INVESTMENT DECISIONS AND SUPPLY RESPONSE
FOR PERENNIAL CROPS THE CASE OF FLORIDA CITRUS

by

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Historically, the Florida citrus industry has been an important participant in both the U S and international citrus markets During the decade of 1980s however, its productive capacity was substantially reduced by the unprecedented occurrence of several tree-killing freezes These events increased the need for information on the economic structure of investment and output supply of Florida citrus In response to these informational needs, this study investigated the structures of investment and supply response of various Florida citrus varieties.

In general, the output of the Florida citrus industry can be varied through planting decisions in the long run and through cultivation decisions in the short run These decisions possess differential dynamic structures and hence they represent alternative adjustment mechanisms for the Florida citrus industry Because of the qualitative differences among investment decisions, economic analysis of the Florida citrus investment

and supply response requires the separate investigation of planting and cultivation decisions. A complete structural system of planting and cultivation decisions was specified for different Florida citrus varieties. In the absence of the necessary data for direct structural estimation of Florida citrus tree planting decisions, new plantings and replantings were considered latent variables and a structural system was estimated within the framework of a dynamic unobserved components model. Structural output relationships, capturing short term cultivation decisions were directly estimable.

CHAPTER 1
PROBLEM STATEMENT AND OBJECTIVES OF THE STUDY

Introduction

Historically, the United States has been an important citrus producing country. During the decade 1978-79 to 1988-89, for example, the average U.S. shares of the world's orange and grapefruit production were 27 and 71 percent, respectively (Citrus Summary). Florida is the most important citrus producing state in the U.S. Over the last decade, Florida accounted on average for 73 percent of the orange production and 78 percent of the grapefruit production in the U.S. (Citrus Summary).

As the largest domestic producer, the Florida citrus industry is influential in both the domestic and international citrus markets, as well as to the Florida economy. For instance, the value of the 1988-89 Florida citrus production was nearly two billion dollars and represented one third of the total cash receipts generated by all agricultural commodities produced in Florida (State Financial Summary). Activities such as picking, hauling, packing, and processing, which follow production, generate additional revenues and employment and magnify the importance of the citrus industry for the state of Florida.

A great deal of economic research has been devoted to demand and marketing problems of this multi-billion dollar industry. Little attention, however, has been directed towards studying the economic structure of investment and supply of Florida citrus or forecasting their

future trends. Reports on projected investment and supply trends of Florida citrus are published by the Florida Department of Citrus annually. These projections are based on deterministic extrapolation of past trends in investment and supply. This approach is useful for short run forecasting when previous trends are likely to persist. It is inappropriate, however, for long run forecasting as it does not account for the stochastic processes and/or the economic structures generating the observed time paths of Florida citrus investment and supply. Furthermore, the value of this approach for economic and policy analysis is also limited since the projected trends of investment and supply are not tied to any economic or institutional factors.

Two studies have attempted to analyze the economic structure of the Florida orange industry (Powe, McClain), while no such studies have been conducted for the Florida grapefruit industry. Powe developed a simulation model of the Florida orange industry and examined the effects of alternative inventory, pricing, advertising, and supply control policies on the industry's performance. McClain developed a Monte Carlo simulation model of the world orange juice market. Within this framework, McClain investigated the impacts of demand and supply structural changes as well as changes in trade policies on the evolution of the world orange juice market. The emphasis in Powe's and McClain's studies was on policy and trade issues, and the treatment of orange investment and supply response was limited.

The level of aggregation in these studies poses additional problems. Florida orange and grapefruit production represent the output of several different varieties with differing end uses, profitability levels, and

production risks. Furthermore, substantially different trends have been observed for some varieties over the last twenty-five years. Hence aggregation across varieties could obscure important behavioral differences with uncertain outcomes for the implied structure of the aggregates.

During the last decade, the unprecedented occurrence of several severe freezes substantially reduced the productive capacity of the Florida citrus industry. Questions have been raised with regard to the industry's ability to overcome strengthened competition from Brazil in the orange market, rising land costs, environmental regulations, and other economic problems, in attempting to return to pre-freeze productive capacity levels. As such, informational needs on the economic structure of investment and supply response of Florida citrus have been intensified.

The overall objective of this study is to investigate the economic structure of investment and supply response for various varieties of Florida citrus. Specifically, the influences of such factors as input and output prices, technological change, uncertainty, institutional arrangements, and weather on investment and supply of Florida citrus must be disentangled and quantified.

Section two discusses recent events that have contributed to the transitory state of the Florida citrus industry and have shaped the economic environment for investment in Florida citrus. Section three evaluates the needs of economic research as they relate to the Florida citrus industry and presents the specific objectives of this study. Finally, section four defines the scope of the study.

Recent State and Economic Environment of the Florida Citrus Industry

The Florida citrus industry experienced significant expansion during the decade of 1960s. Bearing acreage of all Florida citrus increased from 507.3 to 849.4 thousand acres between the 1963-64 and 1970-71 seasons. The industry's growth was founded on increasing demand for processed citrus. Given its orientation towards citrus processing, Florida experienced significant gains in market shares by capitalizing on demand shifts. During the last decade, however, the bearing acreage of the Florida industry decreased by approximately thirty percent and the industry entered a transitory state. The main contributing factor of the reductions in the bearing acreage of the industry during this period was adverse weather.

Extreme weather conditions, particularly freezes, can affect both the short and long run levels of citrus production. When low intensity freezes occur, blooms, mature fruit, and new growth may be damaged with output level being reduced only in the short run. Tree-killing freezes, however, decrease production for an extended period of time by reducing the bearing tree population. The fact that the time lag between replanting and full productive maturity of a citrus tree can be up to fifteen years, indicates that the effects of adverse weather in citrus production can be long lasting. Since the beginning of the century, approximately fifty freezes of varying intensity have been recorded in Florida's citrus producing areas with major freezes occurring roughly once every ten years (Miller). This pattern, however, was interrupted in the 1980s when several major freezes occurred between 1980 and 1989. Freezes between 1980 and 1986 resulted in an estimated loss of 142 million boxes

of citrus (McClain) and 9.1 million productive trees (Gunter and Fairchild) while losses from the freeze in December 1989 have not yet been quantified. The immediate economic consequences from these freeze-induced reductions in supply have been devastating for the Florida industry. Commensurate with the extensive losses in revenue from reduced levels of production, Florida also lost large portions of its shares in domestic and international markets. Florida's lost share in the processed orange market were captured primarily by Brazil through sizable expansions in bearing acreage and production.

The severe freezes of the last decade re-defined the production and investment risk of Florida citrus with still unknown consequences for the long run adjustments of the industry. Florida citrus producers have initially reacted to the increased risks through spatial and varietal adjustments in the new plantings and adoption of improved technologies. Planting activities have been marked by a southward migration due to the lower risk of freeze occurrence in the southern portion of the state. Furthermore, in the areas which were heavily affected by the recent freezes new plantings are mainly cold tolerant varieties (Miller). Extensive technical innovation was also induced by the freezes. Numerous technological advances in citrus production have become available in the last fifteen years with the most notable being improved root stocks, high density planting systems, and improved irrigation and fertilization systems. These technologies were being slowly adopted due to the large initial investment required for adoption, the longevity of the tree stock, existing irrigation systems, as well as other capital already in place. However, extensive investment directed towards replacing the freeze

damaged trees has allowed the new technology to be installed at a faster pace

In addition to the weather related influences, the costs of investment in Florida citrus have been rising over the last decade with yet unidentified consequences on the levels of investment and supply. The increased investment costs can be attributed to such factors as rising land values, environmental regulations, increasing real interest rates, and reductions in the economic incentives in citrus investment through the introduction of the 1986 Tax Reform Act (TRA).

The rapid population growth experienced by the state of Florida in recent years has led to increased competition between agricultural firms and developers for the available land and has resulted in increased land prices. The trends of rising land values are expected to persist in the future as Florida's population is expected to continue growing. Increasing land values not only inflate the cost of new citrus grove developments but also apply cost pressure to existing groves as they imply increasing opportunity costs for citrus production.

Environmental regulations, related primarily with water use, have also added to the cost of new investment in Florida citrus during the last decade. Five regional water management districts, charged by Chapter 373 of the Florida Statutes to manage Florida's water resources, overlook a number of state and local regulations related to water use. These regulations initiated expensive and lengthy processes for acquiring development, well construction and water use permits for new groves. Engineering studies, primarily on the property's drainage, and environmental studies with special attention to wetlands and endangered

species utilizing the area as a habitat are required before a permit for grove development is granted. Well construction and water use permits are also needed for securing property rights on ground water for irrigation purposes. Aside from the procedural costs of acquiring the permits, the costs to new grove development implied by the environmental regulations are sizable because they usually require land set-asides as conservation zones and costly low volume irrigation systems. In addition, these procedures often result in costly delays since for certain environmentally sensitive areas in Florida the period between initiating and completing the development of the new grove can extend up to two years.

Rising real interest rates have put additional pressure on the cost of citrus investment during the last decade. From a low of negative values in the 1970s, real interest rates increased to a high of about seven percent in 1984 and since then have stabilized to an approximate rate of five percent per year. The extent to which increased real interest rates have affected the level of investment in Florida citrus has not yet been quantified.

An additional change that could potentially have a measurable impact on the investment in Florida citrus is the recent revision in the income tax code. The 1986 TRA introduced important changes in the tax rates, eliminated capital gains deductions and investment tax credit, and reclassified citrus groves from a five-year accelerated cost recovery system property to a ten-year straight line depreciation system property. Hoss et al. have shown that the 1986 TRA significantly reduced the potential importance of tax considerations in the citrus investment decision.

Increased costs of investment and production risks should be

expected to effect investment in Florida citrus negatively. The exact size of such negative effect, however, is not known. Economic theory suggests that producers will continue to invest in Florida citrus as long as the flow of discounted expected revenues pays for the cost of the initial investment, the variable production costs, and the rents to the fixed factors over a given planning horizon.

If recent planting rates are indicative of the firm's expectations on citrus profitability, then it may be inferred that citrus production is still regarded as a very profitable enterprise. A great deal of price uncertainty, however, has also surfaced in recent years. This uncertainty is a result of the realization that possible overcapacity of the Florida citrus industry would almost certainly result in a period of low prices. Such concerns are not unjustified. Significant productivity gains are expected due to extensive technological change, spatial and varietal adjustments, and the changes in the age distribution of the tree stock due to the recent heavy plantings. If planting rates continued to be similar to recent levels, bearing acreage would reach or surpass pre-freeze levels within only a few years. Thus, the Florida citrus industry could potentially reach productive capacity levels greater than the ones of the 1970s which could initiate a period of low prices. In conclusion, the future levels of Florida's productive capacity remain to be seen, however, the implied price uncertainty may prove to be the most limiting factor for investment in Florida citrus.

Problem Statement and Objectives

Florida citrus production, due to its dynamic nature, implies long planning horizons and significant initial capital investments for the establishment of the grove. Positive returns to investment are realized after six to ten years (Ford et al.) and the productive life of investment normally extends over several decades. Production uncertainties are prominent in Florida citrus cultivation since freezing temperatures and diseases can reduce annual output, but more importantly, the producing tree stock. Furthermore, future prices and costs are not known with certainty when economic decisions are made. Due to this inherent uncertainty, production and investment decisions must depend on long term expectations of relevant economic and institutional factors. Hence, information on the economic structure and future trends of supply for various Florida citrus varieties could assist in the formation of expectations and economic decisions of the Florida citrus producers.

Recent adjustments in the Florida citrus industry have magnified price uncertainty and have increased the demand for information on the current economic structure and future trends of the industry. Interest in such information among Florida citrus producers is apparent in a survey of 331 Florida citrus farms performed in 1987. Among twelve different categories of information problems and concerns, the five most important, as ranked by the firms, were related to short and long term trends of citrus output, prices and profitability as well as factors that may affect them (Ismail et al.).

Despite the potential value of information on the economic structure and future trends of different Florida citrus varieties to citrus

producers, such information is not currently available. The overall objective of this study is to fill this informational gap through an empirical investigation of investment and supply response for various Florida citrus varieties. The specific objectives of the study are as follows:

1. to explicitly consider the formal optimization problem of the Florida citrus firm, and its implications on the specifications of investment and supply response functions,
2. to develop and estimate appropriate empirical models which conform with the properties of the theoretical and technological considerations on investment and supply response for various Florida citrus varieties.

The derived empirical results could be used for economic and policy analysis as well as for forecasting of future production and investment trends for various Florida citrus varieties. Such information is expected to assist citrus producers, prospective investors, and other market participants in their decision making process.

Scope

The investment and supply response structures of early midseason oranges, late oranges, colored seedless grapefruit[1], white seedless grapefruit, total oranges, and total grapefruit are investigated in this study, over the period 1968 to 1988. Early midseason and late oranges represented over 98 percent of total orange bearing acreage, while colored and white seedless grapefruit represented 92 percent of the total bearing grapefruit acreage in 1988-89. Seedy grapefruit is not considered since

[1] Colored seedless grapefruit is also known as pink seedless grapefruit.

its importance has been consistently decreasing over the last twenty years.

Early and midseason varieties accounted for 53 percent of the total bearing acreage in round oranges while the rest was represented by late varieties (valencia) in 1988-89. For both varieties, over 90 percent of production is usually directed to the processed orange market. Late varieties are more in demand for their suitable color characteristics. However, late varieties also carry a greater production risk since they are vulnerable to freeze damage. Early and midseason varieties assume much lower production risks since, for the most part, they are harvested before the beginning of the freeze-sensitive period of the year. The desired color characteristics and higher production risks are reflected in a price premium that late varieties enjoy over early and midseason orange varieties.

Colored seedless grapefruit varieties represented 44 percent of the total grapefruit bearing acreage while white seedless varieties accounted for 48 percent in 1988-89. Colored varieties are mainly produced for the fresh market where over 65 percent of the total production is sold. White varieties are mainly directed to the processed market where over 65 percent of total production is sold. Because of their different utilization ends, colored varieties have experienced higher prices over the last twenty years. In recent years, however, the price differential between the two varieties has been decreasing.

The relative trends of bearing acreage and plantings for the colored and white varieties have diverged considerably over the last twenty years. Driven by expectations on an expanding European market for colored fresh

fruit and changing consumer preferences, bearing acreage of colored varieties almost doubled over the last twenty years. In contrast, bearing acreage devoted to white varieties remained fairly stable over the same period. Relative trends of bearing acreage and plantings for early-midseason and late orange varieties have been comparable over the last twenty years. Specifically, bearing acreage of both orange varieties experienced considerable growth in the 1960s and significant drops due to freeze damages in the 1980s. The extent to which differences in prices production risks, utilization ends, and observed trends among separate citrus varieties imply distinct investment and supply response structures is investigated in this study. The effects of aggregation across varieties are also considered by examining the investment and supply behavior of total oranges and total grapefruit.

CHAPTER II
THEORETICAL CONSIDERATIONS

Introduction

The analysis of acreage response, the derived demand for land and associated capital, falls within the standard neoclassical model where optimal input use is derived relative to a firm's objective function given the state of technology and the expected time paths of the state variables (prices, weather, etc.) over a finite planning horizon. Substitution of the optimal input levels in the production function determines the firm's optimal output response. Within this framework, input demand and output supply are conditional on the underlying technology. Thus, in empirical analysis of acreage and supply response[1] special attention must be given to the identification of the technology underlying the cultivation of interest.

This chapter examines the general features of perennial crop cultivation and their implications on the appropriate representation of technologies and the firm's optimal output response. The agronomic characteristics of perennial crops, the implied technology, as well as the

[1] A typical feature of agricultural production is the less than full control of the farmer on the final output. Because of the usual divergence between planned and actual output a number of economic studies have approximated planned output with planted acreage. For this reason the notions of acreage response and supply response have often been used interchangeably. In this study acreage response refers to an agricultural firm's land adjustments or planting decisions. The notion of supply response is reserved for the broader set of decisions which include planting decisions, variable input utilization rates decisions, technology adoption, and harvesting decisions.

associated decision set in perennial crop supply response are discussed in section one. The most important theoretical and empirical studies on perennial crop supply response are reviewed in section two and the degree of success in dealing with the specific agronomic peculiarities of perennial crop technologies is appraised. The appropriate technologies and the optimization problem of the Florida citrus firm (or their aggregate) are considered in section three. The implications of the optimization process for econometric modelling of the Florida citrus acreage and supply response are considered in section four.

Agronomic Considerations in Perennial Supply Response

The set of decisions associated with output adjustments in response to prices and other economic or institutional factors available to the perennial crop firm is more rich and complex than the ones for annual crops. These decisions may be categorized into three subsets: planting decisions, cultivation decisions, and harvesting decisions (Bellman and Hartley).

Planting decisions refer to all the possible options available to the farmer in controlling the firm's future productive capacity towards a desired level through adjustments of the tree stock. The farmer can increase the future productive capacity by increasing the acreage devoted to perennial crop cultivation through new plantings or reduce it through uprootings and diversification of land to alternative uses. The farmer can also adjust the future productive capacity of the firm through changes in the age composition of the existing productive stock. Specifically, the farmer can increase the productive capacity of the

existing land allotment through uprootings of aging and less productive vintages followed by replantings and, for some perennial crops, through stumping.[2] Hence, the total adjustment of the firm's future productive capacity in any given year is the net effect of all the planting decisions which modify both the total cultivated area and the age composition of the tree stock.

Cultivation decisions refer to the firm's choice set of variable input utilization rates which are conditional on each year's tree stock and its age composition. Such decisions can significantly modify not only the current but also the future productive capacity of a given tree stock by shifting its age-yield profile. The effects of annual fertilizer, labor, and material utilization rates on yields are physically distributed over a number of years. Thus, in deciding on the annual input levels the farmer must take into account both the temporal and intertemporal input substitution possibilities. In addition, the farmer must consider the substitution possibilities of inputs across age classes (vintages), since different age classes can exhibit varying response rates to input applications. Hence, cultivation decisions involve joint choices on the input levels and the associated vintages where the specific inputs are applied.

Planting and cultivation decisions jointly determine the total productive capacity of the tree stock available to the firm and thus its

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[2] It should be noted that all planting decisions are influenced by considerations on new technology adoption. Availability of improved cultivars, root stocks, and/or preferable tree densities represent additional production possibilities to the farmer's adjustments towards a desired level of future productive capacity.

potential annual output. However, the actual annual output produced by the firm may differ from the potential output due to random factors (weather conditions, diseases, etc.) and/or harvesting decisions. Specifically, the firm would harvest only part of the available crop if the marginal cost of harvesting became greater than the output market price. Furthermore, for perennial crops which are harvested continuously over a year, such as rubber and tea, the intensity of harvesting in one year can substantially modify the yields of subsequent years. Thus, the intertemporal output substitution possibilities may lead the firm to harvest only a portion of the potential output in each given year.

The foregoing discussion serves to emphasize the following three important points. First, an appropriate perennial crop supply response theory must account for the following interdependent investment and production decisions:

(a) Adjustments in planted acreage and its age distribution.

(b) Adoption of improved cultivars and other new technologies.

(c) Utilization rates of variable inputs across various vintages of the tree stock.

(d) Levels of the potential output harvested.

Second, perennial supply theory must be dynamic because of the following intrinsically dynamic characteristics of the firm's supply response:

(a) The perennial production process is itself fundamentally dynamic due to the existing input-input and output-output intertemporal substitution possibilities.

(b) Planting and cultivation decisions which are jointly performed in

any given period become state variables (or constraints) for planting and cultivation decisions in subsequent periods

(c) The existence of costs of adjustment, which penalize rapid investment and disinvestment, may imply sluggish adjustment of the fixed factors towards their desired or optimal levels

(d) The natural gestation and full-yield response lags associated with perennial crop production, along with the above dynamic aspects of the process, impose forward-looking behavior for the perennial crop firm

Third, an adequate depiction of perennial technologies must allow for temporal, intertemporal, and inter-vintage substitution possibilities to be represented. This last fact endorses the use of vintage production functions with heterogeneous capital as a useful analytical tool in studying the perennial acreage and supply response structure.

Previous Studies[3]

A complete theoretical framework for studying the dynamics of perennial supply response did not appear in the literature until recently. Bellman and Hartley developed a comprehensive theoretical model with vintage technologies where planting, cultivation, and harvesting decisions are all present in the firm's decision set. The producer is assumed to maximize the discounted present value of profits over a finite planning

[3] This section reviews only the studies that have contributed new theories and methods to the literature econometric perennial supply response analysis, relevant to this study. The collection presented here is not exhaustive. For additional econometric studies see Askari and Cummings; for simulation studies of perennial supply see Bartelle and Price and McClain, and for synthetic studies of perennial supply see Knapp and references therein.

horizon by jointly selecting the rates of investment, input utilization, and harvested output. This problem is shown to be a dynamic programming problem for which no closed form solutions are available due to its complex dynamic structure. Because of this complexity, Bellman and Hartley (p.66) concluded that "...it will often be impossible to obtain reliable direct estimates of the parameters in the dynamic technology based solely on macro time series data without making extreme simplifying assumptions." They suggested that micro-level panel data be combined with the usually available macro data to provide structurally relevant parameters.

Trivedi developed a similar but more limited vintage model in which investment and supply decisions for the profit maximizing firm are analyzed through classical nonlinear programming concepts. Within this framework, the intricate input and output substitution possibilities of perennial production are uncovered and the jointness of planting, cultivation, and harvesting decisions is emphasized. However, as with Bellman and Hartley, closed form analytical solutions for the supply problem could not be derived from the optimization conditions.

The previous theoretical studies have clearly demonstrated the inherent difficulties in perennial crop supply analysis which arise from the complex dynamic structure of perennial technologies. In empirical analysis of perennial investment and supply response, however, further complications arise from empirical issues such as the specification of unobserved expectations and "desired" levels of acreage. Because of these difficulties and in the absence of closed form analytical solutions to the optimization problem, empirical studies have routinely resorted to ad hoc

specifications of acreage and supply response functions

Empirical aggregate supply response studies for perennial crops first appeared in the economic literature in the early 1960s and the majority have been cast within the econometric framework. French and Bressler developed the first meaningful perennial acreage response model in terms of total plantings and removals in lemon production. Tree plantings were specified as a function of long run expected profits and expected removals, proxied by the number of trees over twenty-five years of age. Removals were specified as a function of short run expected profits, number of trees over twenty-five years of age and a proxy for urban expansion. Profit expectations were assumed to be formed as averages of previously realized profits.

Bateman and later Behrman, offered the first explicit attempts to adapt Nerlove's (1958) supply response model developed for annual crops, to perennial crop cultivation. Bateman assumed that farmers maximize the present value of expected profits with respect to acreage in cocoa production. Thus, the author postulated an acreage response function where planted acreage is a function of discounted own and substitute prices. In the absence of planted acreage data Bateman re-specified the model in terms of output. Assuming that expectations are adaptive, Bateman estimated a single equation reduced form where output is a function of lagged own and substitute prices, lagged weather, and lagged output. Behrman estimated a similar relation although he derived the final reduced form through a partial adjustment approach.

French and Mathews introduced a more complete model for asparagus supply response. Two separate relationships were specified to describe

total plantings and removals. These relationships were subsequently combined to give the desired bearing acreage. A separate relationship was employed to explain yields in terms of variations in age distribution of the existing tree stock, productivity growth, and weather conditions. Changes in yields and acreage were then combined to explain variations in output. Finally, specification of the unobserved expectations and desired acreage in terms of lagged observable variables completed the model. Estimation of the structural system was not possible due to data restrictions. Instead, a single equation reduced form model which resulted from solving the structural system was estimated. However, the structural parameters were underidentified and could not be recovered from the estimated coefficients.

Rausser offered the first decision theoretic model in the perennial crop supply response literature through an extension of Jorgenson's optimal capital accumulation model. Within this framework Cobb Douglas and CES production functions were considered as technological representations of California orange production and the supply function was explicitly derived from the firm's optimization problem. Such production technologies, however, imply homogeneous capital which is uncharacteristic of the heterogeneous capital perennial crop production. Summary measures of age-yield profiles were used to standardize capital inputs so that services were proportional to the stocks. In the absence of adjustment costs, the implied solutions to the optimization problem were myopic, also atypical to the intrinsically dynamic perennial crop supply response. For that matter, Rausser postulated sluggish adjustment of capital stock towards its equilibrium levels on the basis of

biologically determined lags, information and response lags and other rigidities.

Wickens and Greenfield proposed a simpler decision theoretic model where they employed a vintage production function with heterogeneous capital input. By explicitly considering convex costs of adjustment in the firm's objective function, the authors obtained smooth adjustment paths from the optimization problem. Under the assumptions of quadratic adjustment costs and zero substitution possibilities between fixed and variable inputs, analytical solutions for the investment paths were possible. The authors also allowed for the possibility that only part of the potential output is harvested by adding a harvesting equation. Although Wickens and Greenfield specified separate structural equations for production technology, total investment, and harvesting decisions, they estimated a single reduced form equation for coffee supply due to data limitations. As in previous cases, the structural parameters were underidentified.

Akiyama and Trivedi and Hartley et al. were the first to note that new plantings and replantings are qualitatively different investment decisions. Akiyama and Trivedi used a vintage production function and, following Trivedi's approach, they defined planned output as the profit maximizing level of output. Actual output was allowed to differ from planned output due to stochastic supply shocks and unrealized expectations. Within this framework, output supplied by the firm becomes a function of potential output and relative errors in price expectations. Variants of the error correction model were used to define theoretically consistent relationships for new plantings and replantings. Akiyama and

Trivedi estimated structural relationships for supply, new plantings, and replantings for tea production in India, Sri Lanka, and Kenya. Their estimations were facilitated by the availability of detailed time series on new plantings, replantings and uprootings, output and age-yield profiles underlying tea production in the various producing regions.

Hartley et al. also estimated a structural system of supply response. Using a variant of the Wickens and Greenfield model and detailed data on new plantings and replantings, output, age yield profile, and age distribution of the stock they examined separately the harvesting, replanting, and new planting decisions on rubber supply in Sri Lanka.

Despite the inventiveness of the empirical studies in dealing with complex dynamics, specification of unobserved variables, and data constraints, some limitations must be explicitly recognized. First, the majority of the empirical studies have been tempered by the availability of data. The value of a structural approach in uncovering the dynamics in perennial supply response has long been recognized. The required data sets for estimation of structural systems, however, are quite involved and usually unavailable. For this reason, empirical analysts have resorted to single reduced form equations adjusted for the specific features of a particular perennial crop, and attendant data restrictions. The emphasis in these studies is on the derivation of supply elasticities. When short run output adjustments are allowed (through harvesting decisions), the derived elasticities are difficult to interpret since the short and long run output responses cannot be disentangled. When only long run output adjustments are allowed, the derived price elasticities are interpreted as long run supply elasticities. Akiyama and Trivedi have noted, however,

that from a priori considerations it is not apparent that there always exists a heterogeneous capital stock of unique composition which corresponds to a given price configuration. This implies that the concept of long run supply elasticity may not be well defined in perennial crop supply response. To the extent such assertions are valid, the value of reduced form specifications is questionable.

Second, although the importance of the dynamic interdependence among the various planting decisions has been stressed in theoretical studies, such interdependencies have been systematically ignored in empirical research. Indeed, even in cases where detailed data sets permitted estimation of structural systems, interactive estimations of new plantings and replantings were not considered. Partial care has been taken for the jointness between replantings and uprootings in only a limited number of studies (e.g. Akiyama and Trivedi).

Third, the treatment of the unobserved variables in empirical perennial crop supply studies is mainly based on the notions of certainty equivalents[4] and stationary expectations (Nerlove, 1979). Several different mechanisms of expectation formation which have been advocated, such as naive (Ezekiel), adaptive (Cagan), rational (Muth), and quasi-rational (Nerlove et al.), are methods of arriving at certainty equivalence of uncertain variables. In general, rational expectations are considered the most theoretically consistent form of expectations (Fisher, Ekstein). Little has been done, however, to justify the autoregressive

[4] As explained by Nerlove and Bachman (p.540), the notion of certainty equivalents allows " each uncertain variable to be replaced by one or more variables the values of which, if expected with certainty, would lead to the same solution as that which would be obtained by treating the decision problem to its full generality."

expectation forms usually employed in perennial crop supply studies, which typically result from empirical experimentation. Some care in justifying the choice of expectation formations, a priori, would lend more validity to the specification of unobserved variables in empirical perennial crop supply studies.

Fourth, most of the studies have focused on explaining planting decisions, and in some cases, harvesting decisions. Cultivation decisions have most often been assumed away by invoking putty clay technologies which imply zero substitution possibilities between the fixed tree capital stock and all other variable inputs. Although this assumption is often justified on model tractability grounds, it must be recognized that it is fairly restrictive. For most perennial crops, cultivation decisions can substantially shift the age-yield profile of any given tree stock. Whether the producers maintain fixed input management practices or respond to price changes through short run adjustments in input utilization rates should be a matter of empirical assessment.

Florida Citrus Technology and the Firm's Optimization Problem[3]

The general agronomic characteristics of perennial production previously described are only partially relevant to Florida citrus production. Replantings are performed regularly in order to replace trees damaged by pests, diseases, and freezes. New plantings are also an important segment of total plantings, especially in expansionary periods of the Florida citrus industry. Uprootings of uneconomic vintages are not

[3] The developments in this section follow theoretical advancements presented in Trivedi adapted to technological characteristics specific to the Florida citrus industry.

observed, however, in Florida citrus production since well-cared older citrus trees continue to be economically productive. Annual cultivation decisions which include fertilization, water, and pest management can significantly modify the underlying yield-age profile of a given citrus tree stock. Finally, biennial cycles or other output intertemporal substitution possibilities and economic abandonment of citrus fruit are not observed in Florida citrus production.[8] Hence, harvesting decisions need not be considered in explaining Florida citrus supply. Under these simplifications in the pertinent decision set, it is of interest to consider the firm's optimization problem in order to examine the dynamic properties of Florida citrus investment and supply and to provide guidance to econometric specifications.

Foremost, it is assumed that the production technology of Florida citrus can be depicted by a set of vintage production functions with heterogeneous capital input, such as

$$(2.1) \qquad \{ f^i (k(t,v), l(t,v)) \} \qquad v \in V,\ i \in I$$

where $k(t,v)$ represents capital input of vintage v employed in time t, and $l(t,v)$ represents a vector of variable inputs combined with $k(t,v)$. For citrus production, capital input $k(t,v)$ may be thought as a composite

[8] Partial harvest of the potential output introduces a discontinuity in the derivative of output with respect to prices (Nerlove 1979). This discontinuity implies that exact or approximate certainty equivalents for the unknown future prices do not exist. A number of empirical studies have overlooked this theoretical inconsistency by introducing harvesting relations to explain short run variations in actual output while assuming the existence of certainty equivalents in formulating price expectations. This caveat does not apply to this study since all potential output is harvested annually.

input of area planted with citrus trees under some fixed density and associated capital inputs such as irrigation systems. The input vector $l(t,v)$ can also be re-defined as a composite input of labor and other variable inputs used in fixed proportions with it, without loss of generality. Index i is used to describe separate technologies such as various citrus hybrids, root stocks, and tree densities. These factors may imply different substitution possibilities among variable inputs. The standard concavity properties of the production function are maintained so that $\partial f^i(t,v)/\partial l > 0$ and $\partial^2 f^i(t,v)/\partial l^2 < 0$, hold across all productive vintages.

For Florida citrus, a standard gestation period G^i is required before the tree stock can produce any output. The gestation lags are allowed to vary with technology i in order to account for observed regularities. For example, high density planting technologies imply three-year gestation lags while low density planting technologies result into four year gestation lags. Under these conditions, the vintage production function can be written as

$$
(2.2) \qquad q^i(t,v) = \begin{cases} f^i[k(t,v),\ l(t,v)] & \text{if } t-v > G^i \\ 0 & \text{if } t-v < G^i \end{cases}
$$

Since $t-v$ measures the age of the tree stock, equation (2.2) suggests that only mature vintages produce positive output.

A specific age-yield profile is assumed to exist for each technology i so that yields gradually increase with the age of the tree stock over a twenty year period and they subsequently level off. A given age-yield

profile may be inferred by allowing the productivity of capital $k(t,v)$ to vary in a determinate way with vintage v. The age profile can be shifted, however, through variations in the mix of $k(t,v)$ and $l(t,v)$. Specifically, assuming constant returns to scale and dividing $q^i(t,v)$ by $k(t,v)$, results gives

$$(2.3) \qquad \frac{q^i(t,v)}{k(t,v)} = f^i\left[\frac{l(t,v)}{k(t,v)}\right]$$

which defines the age-yield relationship for technology i. From (2.3), it is evident that the age-yield relationship is dependent on the "labor" to capital ratio for each given vintage v and technology i.

A simple extension of the vintage production function in (2.2), can also be used to incorporate possible intertemporal substitution possibilities among inputs. Specifically, the output of mature vintages in current period t is allowed to vary with input levels applied in period $t-p$ as

$$(2.4) \qquad q^i(t,v) = f^i[k(t,v),\ l(t,v)\ |\ l(t-p,v)],$$

thus the current period output is conditional on past period "labor" input applications. For notational convenience, such conditional statements will be implied rather than explicitly stated from now on.

Total output obtained from a specific mature vintage v, is the sum of outputs from this vintage across all relevant technologies

$$(2.5) \qquad q(t,v) = \sum_i q^i(t,v) \qquad\qquad i \in I,\ v \in V_m,$$

where V_m denotes the set of mature vintages. The total output of all mature vintages is then given by

$$Q(t) = \sum_{v} q(t,v) \qquad v \in V_m \tag{2.6}$$

The net change in capital for each vintage v and period t may be specified through the capital depletion and investment equations

$$k(t,v) = d(t,v)\, k(t-1,v) - D(t,v) \qquad v \in V, \tag{2.7a}$$

$$k(t,t) = r(t) + n(t) \tag{2.7b}$$

Equation (2.7a) suggests that capital of vintage v in period t is the remainder of capital of vintage v in period t-1, after depreciation $d(t,v)$, and stock reductions due to stochastic factors $D(t,v)$ have been accounted for. Depreciation $d(t,v)$ is used to account for tree deaths attributable to diseases and pest infestations and is considered to be proportional to the tree stock. Depletion $D(t,v)$ describes the effect of random tree-killing freezes. Equation (2.7b) states that total investment in period t is the sum of new plantings $n(t)$ and replantings $r(t)$.

It is now assumed that the Florida citrus firm bounded by the technological constraints described by the relationships (2.1) through (2.7) maximizes discounted net revenues over a given planning horizon by choosing the levels of new plantings, replantings, and "labor" inputs as well as appropriate technologies. In solving its dynamic optimization problem, the firm must have knowledge of the time paths of future output prices $(p(t))$, input prices $(w(t))$, planting costs $(c(t))$, and interest rates $(\delta(t))$, which are revealed in perfectly competitive markets. Since knowledge of future prices and costs with certainty is not possible, it is

assumed that these state variables can be replaced by their certainty equivalents. Finally, it is assumed that there exist convex costs of adjustment $\phi_1(n(t))$, $\phi_2(r(t))$ for new plantings and replantings respectively. Such costs are assumed to penalize rapid adjustments of the firm towards the optimal level of capital stock. Specifically, fixed costs of "pushing" dead trees out of the grove and replanting, as well as costs incurred due to special cultural practices required for the resets, often induce firms to replant every two or three years so that these fixed costs are distributed over a greater number of trees. For new plantings, search costs for appropriate land, and extra costs of accelerating the process of acquiring permits and establishing the grove may induce sluggish adjustments.

Based on these assumptions, the optimization problem of the Florida citrus firm can be formally stated as

$$\text{(2.8)}\quad \max \sum_t (1+\delta(t))^{-1}[p(t)Q(t) - w(t)l(t) - c_1(t)n(t) - c_2(t)r(t) - \phi(n(t)\ r(t))]$$

$$\text{(2.9a)}\qquad k(t,v) = d(t,v)\ k(t-1,v) - D(t,v)$$

$$\text{(2.9b)}\qquad k(t,t) = r(t) + n(t)$$

$$\text{(2.9c)}\qquad n(t)\geq 0\quad r(t)\geq 0,\ l(t)\geq 0$$

$$\text{(2.9d)}\qquad k(0,v) = \text{given for all } v \qquad\qquad v \in V,$$

where $l(t) = \sum_i \sum_v l(t,v)$ and $\phi(\cdot) = \sum_i \sum_k \phi^i(n(t), r(t))$, and $k=1, 2$

The stated problem of the citrus firm is a nonlinear programming problem and iterative techniques based on the Kuhn-Tucker conditions could be used to derive the solutions. Assuming that all $n(t)$, $r(t)$, and $l(t)$ are strictly positive, classical optimization procedures may be utilized to

obtain the first order conditions of optimality with respect to the decision variables

The choice of appropriate technologies i is the first set of decisions the firm must consider The condition of optimality for a technology i may be stated as

$$(2\ 10)\quad \sum_t [1+\delta(t)]^{-1}\, p(t) q^i(t,v) \geq \sum_t [1+\delta(t)]^{-1}\, \{w(t) l^i(t,v) + c_1(t) n^i(t) + c_2(t) r^i(t) + \phi^i(n^i(t), r^i(t))\}$$

The inequality sign in the above condition is necessary due to the fact that the choice of technology is discrete and may not always hold at the margin Given that no budget or borrowing constraints have been specified in the firm's problem, condition (2 10) implies that every technology i which adds net revenue to the firm's objective function will be employed If large fixed costs of adopting new technologies exist, however, important discontinuities are introduced and significant changes in costs and benefits must take place before one technology is replaced by another

The rates of new planting and replanting investments that maximize the flow of net revenues to the citrus firm are given by

$$(2\ 11a)\quad \frac{\partial \phi^i_1(\ )}{\partial n(t)} + c_1(t) = \sum_t [1+\delta(t)]^{-1}\, p(t)\, \frac{\partial f^i}{\partial n(t)}$$

$$(2\ 11b)\quad \frac{\partial \phi^i_2(\ )}{\partial r(t)} + c_2(t) = \sum_t [1+\delta(t)]^{-1}\, p(t)\, \frac{\partial f^i}{\partial r(t)}$$

Conditions (2 11a) and (2 11b) suggest that the firm will continue to invest in new plantings and replantings up to the point that the present value of the marginal revenue product of an additional unit of capital

equals its marginal cost The adjustment costs and the production function under these conditions are specific to the type of technology used and consequently, the choice of technology and rate of investment are jointly determined It should also be noticed, that if the adjustment and direct planting costs of replantings are lower than those of the new plantings, it is likely that replantings will be exhausted before any new plantings are realized in the firm's optimal solution Although this may not be an unrealistic condition, it is certainly restrictive It is possible, however, to eliminate this restriction by allowing certain technologies to be available only through new planting investment, a provision that conforms with investment possibilities in Florida citrus

Finally, the optimal utilization levels of "labor" inputs for each given technology are determined by the conditions

$$(2\ 12)\quad w(t) = \frac{\partial f^i}{\partial l(t,v)} = \frac{\partial f^j}{\partial l(t,v)} \qquad i,j \in 1$$

Condition (2 12) requires that the marginal value product of labor is equalized across all vintages and all technologies, emphasizing the possibilities of substitution across vintages and technologies.

The dynamic behavior of citrus investment and supply can be characterized through optimal paths and steady states derived from the optimality conditions (2 10) through (2 12) With regard to the existence of analytical solutions to the optimization problem (2 8) and (2 9) parallel results to those in Bellman and Hartley and Trivedi are obtained here Specifically, it is concluded that closed form analytical solutions of the investment and supply time paths are not attainable due to the

following contributing factors. First, the existing non-linearities necessitate iterative procedures for the system of the first order conditions to be solved. Second, the dynamic specification of the objective function further complicates the problem. In a similar control problem, Gould established that unless prices, costs, and discount rates could be considered stationary, analytical solutions would not be possible. Under the conditions of fixed proportions between capital and labor, quadratic costs of adjustment, static expectations, and single technology, analytical solutions are possible (Wickens and Greenfield). However, the value of such solutions is limited since a large portion of the dynamic structure of perennial input demand and output supply have been assumed away.

With respect to the existence and of a steady state where a time invariant distribution of capital stock is realized, Trivedi has noted that the necessary conditions require that all prices, costs, and investment rates remain constant over time. Even under such restrictive conditions, however, convergence to steady state may not be possible from any initial conditions.[7] Based on the same arguments, it may also be argued that even if a unique optimal capital stock exists for a given set of prices, it is not clear whether it is attainable from any initial capital stock with a given age distribution. Such conditions would be in agreement with Akiyama and Trivedi's position that the long run supply elasticity may not be well defined for perennial crop.

[7] Probably a more fruitful notion of steady state would refer to the productive capacity of the capital stock rather than the stock itself. It is possible that productive capacity would converge to a steady state from a richer set of initial states through adjustments in the capital stock and/or its age distribution. Such an issue, however, requires further investigation.

Implications for Econometric Modeling

Theoretical considerations are often used to guide econometric design with regard to the appropriate endogenous and exogenous variables to be included in the model as well as the choices of functional forms and stochastic specifications. As evident in the previous section, analytical formulations which incorporate a realistic representation of the Florida citrus technology in the firm's optimization problem are bound to result in intractable models. Thus, the insights that may be gained from these formulations on functional and stochastic specifications in econometric modeling are limited. However, these limitations may not be as consequential since the linear functions and simple error designs used in structural estimations of perennial investment and supply appear to successfully approximate the true underlying structures. Furthermore, a number of important inferences may be drawn from the preceding theoretical considerations which can be used to guide the econometric modeling of the Florida citrus acreage and supply response.

With respect to the endogenous variables relevant to the supply problem, conditions (2.10) through (2.12) suggest that four such variables must be considered: the choice of profitable technologies, the rates of new plantings and replantings, and the optimal levels of variable input utilization. Conditions (2.11a) and (2.11b), imply that the choices of the appropriate technologies are jointly determined with the choices of new plantings and replantings. Therefore, considerations on the rate of investment across different technologies incorporate adjustments through choices on both the rate of investment and the appropriate technology.

Differences in direct costs, adjustment costs, and project

completion lags between new plantings and replantings suggest that these separate investment possibilities represent differential adjustment mechanisms for the citrus firm. Because of their qualitative differences, new plantings and replantings must also be separately explained in an appropriate econometric model. Optimality conditions (2.10) through (2.12) indicate that planting decisions are dynamically interdependent since each investment decision at any given period becomes a state variable for all investment decisions in following periods. Furthermore they also suggest that all planting decisions are jointly performed in any given period. Hence, a theoretically consistent econometric model must allow for the jointness and interdependence of the planting decisions to be represented.

In addition, condition (2.12) suggests that separate relationships for various vintages must be specified which allow for short run output adjustments through cultivation decisions. Such relationships must be conditional on the existing capital stock and its age-yield profile.

The relevant exogenous variables which will be used as explanatory variables in the supply response econometric model can also be inferred from the optimization problem. These variables are expected real prices, costs of production, vintages of the capital stock, and exogenous factors such as freezes and disease infestations. Finally, in the absence of conclusive evidence on the existence of a steady state, special attention must be given to examining the dynamic properties of stability and controllability of the Florida citrus supply system.

CHAPTER III
METHODOLOGICAL AND MODELING CONSIDERATIONS

Introduction

The discussion in the previous chapter illustrated that empirical studies have addressed the problems associated with acreage and supply response for perennial crops with only partial success. The most important obstacle in estimating meaningful structural systems has been limitations in the data. Indeed, such constraints are bound to appear often in empirical inquiries of perennial supply since the data necessary for structural estimation is very demanding. Specifically, time series on new plantings, replantings/uprootings, age distribution of tree stock, underlying age-yield profile, actual yields, prices and costs are required for the estimation of a complete structural system of perennial supply response.

For Florida citrus, a quite rich data base exists over a reasonably long period of time. Total citrus plantings by variety have been reported annually since 1965. Aerial photography methods are utilized for the citrus tree counts and a great degree of accuracy in measurement is attained. Comparisons among subsequent citrus tree inventories allow precise inferences about the age distribution of the citrus tree stocks over time. In addition, data on actual yields of various citrus varieties for four different age categories have been reported annually since 1969, and estimated age-yield profiles for different Florida citrus varieties

are available. Extended time series on costs of production and prices of Florida citrus are also available.

Even with such detailed data, direct estimation of a structural model of Florida citrus supply response is not possible. Although cultivation decisions can be separately examined in structural output relationships, planting decisions cannot be individually estimated. Within the available data set new plantings are not differentiated from replantings, so only an aggregate category of total citrus plantings is being reported. Thus, complete structural estimation of Florida citrus supply response is restricted.

The value of such a structural approach in explaining the dynamics of Florida citrus supply was discussed in the firm's optimization problem. It is the commitment to structural estimation of Florida citrus supply that leads to the methodological developments of the subsequent sections in this chapter. An econometric model which permits structural estimation of planting relationships in the absence of detailed data for the separate planting categories is analyzed in section two. The underlying assumptions and estimation procedures for this econometric model are also discussed in this section. The conditions for empirically investigating the dynamic properties of stability and controllability of Florida citrus planting decisions within the framework of the suggested model are considered in section three. Some concluding comments on the generality of the proposed model are presented in section four.

A Dynamic Unobserved Components Structural Model

The most important property that the econometric model must possess is its ability to overcome the aforementioned data limitations and allow

for structural estimation of Florida citrus planting relationships. Such a structural model requires the unobserved (latent) new plantings and replantings to be explicitly and separately considered. In addition, a proper structural model must conform with the dynamic properties of planting decisions. As was demonstrated in the firm's optimization problem, new planting and replanting investment decisions are dynamically interdependent. Thus, the model should also allow such dynamic features to be represented.

The appropriate structural econometric model may be found in the general area of structural models with latent variables (Goldberger; Aigner and Goldberger; Bollen). Following Bollen, structural models can be classified into three separate categories: (a) structural models that contain only observed variables (b) structural models which include latent variables to be explained in terms of only observed variables (such as in factor analysis) and (c) structural models that contain latent variables explained by endogenous and/or exogenous latent variables and other observable variables. This third category of structural models represents a synthesis of the first two categories and provides a suitable model of Florida citrus planting activities.

A structural model which allows for dynamic interdependencies among latent variables is the <u>dynamic unobserved components model</u> discussed by Engle and Watson. The general form of dynamic unobserved components model can be represented by the relationships

(3.1a) $$x_t = \phi_t\, x_{t-1} + \gamma_t\, z_t + v_t$$

(3.1b) $$y_t = \alpha_t\, x_t + \beta_t\, z_t + e_t \qquad t=1,\ldots,T,$$

where x_t is a vector of unobserved variables, y_t, m_t and z_t are vectors of observable variables and v_t and e_t are vectors of stochastic disturbances. In addition, ϕ_t, α_t, β_t, and γ_t are parameter matrices conformably defined which can be time-varying or constant.

As pointed out by Engle and Watson, the dynamic unobserved components model falls within the general framework of the state-space model which originated in the control engineering literature. Within this framework, y_t is defined as the measurement vector, x_t is termed the state vector, and the exogenous m_t and z_t are referred as the instruments or controls of the dynamic system (3.1). The state vector characterizes the internal configuration of the dynamic system and is itself described by the difference equation system (3.1a) which is composed of the transition equations. Furthermore, the state vector is related to the observable measurement vector via the measurement equations (3.1b). In the case that interest centers on the effects of the instruments on the measurement vector alone, a reduced form representation of the dynamic system is sufficient. However, when the intermediate effects of the instruments on the states is also of interest, a structural model such as (3.1) is necessary.

To facilitate the econometric modeling of Florida citrus planting decisions within the framework of the dynamic unobserved components model, specific interpretations are adopted for the variables in (3.1) and additional assumptions are made. In particular, the unobserved new plantings n_t and replantings r_t are the state variables of the system while the observed total plantings become the measurement variable y_t. Exogenous observable variables which can influence citrus plantings, such as prices and costs, are the instruments z_t of the dynamic system.

In terms of specifying total plantings, the measurement equation (3 1b) can be simplified considerably By definition, new plantings and replantings add up to total plantings. If this additive relationship is considered to hold exactly for all periods, the measurement equation may be stated in deterministic fashion In the case that measurement errors are suspected, stochastic disturbances may be added to the measurement equation For Florida citrus it is assumed that total plantings are measured without error.

Based on these simplifications and assuming that the system matrices ϕ and γ are non-stochastic and time-invariant, the relevant state-space specification for the plantings decision model becomes

(3 2a) $$x_t = \phi\, x_{t-1} + \gamma\, z_t + v_t$$

(3 2b) $$y_t = a\, x_t$$

(3 2c) $$x_t = [r_t\ n_t]' \qquad t=1,\ldots,T$$

where a is now a (1x2) row vector of ones Within this specification, the stochastic disturbances v_t are assumed to be serially uncorrelated with zero mean and covariance matrix V Furthermore, the initial state vector x_0 is regarded as a vector of random variables with mean $\bar{x}_0$ and covariance matrix Σ_0. Finally, the disturbances v_t are assumed to be uncorrelated with the initial state vector x_0.

Estimation of the structural model in (3 2) involves two sets of unknowns, namely, the unobserved variables in the state vector x_t and the unknown parameters in the system matrices ϕ, γ, and V General solutions for estimating these two sets of unknowns are available based on a number of algorithms with most important being the Kalman filter The Kalman

filter is a recursive procedure which provides the optimal estimator of the state vector x_t at time t, based on information on the measurement and control vectors available at time t. For each estimation, the parameters of the system matrices ϕ, γ, and V as well as the initial conditions $\bar{x}_0$, and Σ_0 are assumed known. However, when the disturbances v_t and the initial state vector x_0 are normally distributed, the Kalman filter also permits the estimation of the unknown parameters in the system matrices ϕ, γ, and V. Alternative algorithms, such as the information filter and square root filter, are also applicable for similar estimations within specification (3.2), and in some instances have procedural advantages over the Kalman filter (see Harvey for details).

<u>The Kalman Filter and Estimation of the State Vector</u>. The derivation of the Kalman filter here is based on the assumption that both the disturbance v_t and the initial state vector x_0 are normally distributed. Under these conditions, the Kalman filter computes at each point of time t the conditional mean of the state vector x_t. When the normality assumption is not invoked, the Kalman filter still provides an optimal estimator for the state vector in the sense that it minimizes the mean square error, but there is no guarantee that it yields the conditional mean of x_t.

Let the conditional mean of the state vector x_i based on information up until period k be represented by $x_{i|k}$, that is $E[x_i|y_1,\ldots,y_k]=x_{i|k}$. Further, let $\Sigma_{i|k}$ denote the covariance matrix of the estimation error, i.e. $E[(x_i-x_{i|k})(x_i-x_{i|k})']=\Sigma_{i|k}$. The Kalman filter for specification (3.2) can be derived through procedures parallel to the ones in Chow 1975, and can be outlined as follows:

(3.3a) $\quad x_{t|t-1} = \phi x_{t-1|t-1} + \gamma e_t$

(3.3b) $\quad \Sigma_{t|t-1} = \phi\, \Sigma_{t-1|t-1}\, \phi' + V$

(3.3c) $\quad x_{t|t} = x_{t|t-1} + \Sigma_{t|t-1}\, \alpha'(\alpha\, \Sigma_{t|t-1}\, \alpha')^{-1}\, (y_t - \alpha x_{t|t-1})$

(3.3d) $\quad \Sigma_{t|t} = \Sigma_{t|t-1} - \Sigma_{t|t-1}\, \alpha'(\alpha\, \Sigma_{t|t-1}\alpha')^{-1}\, \alpha\, \Sigma_{t|t-1}$

Equations (3.3a) and (3.3b) give the optimal estimators of the state vector and the covariance matrix of the estimation error at time t, and are known as the prediction equations. As new observations on the measurement vector y_t became available, the estimators of state variable and the estimation error covariance matrix are updated through the updating equations (3.3c) and (3.3d).

The Kalman filter requires as starting values the values of $\bar{x}_0$ and Σ_0. These initial conditions are set equal to $x_{0|0}$ and $\Sigma_{0|0}$ in the prediction equations which are evaluated to give $x_{1|0}$ and $\Sigma_{1|0}$. The predicted values $x_{1|0}$ and $\Sigma_{1|0}$ are subsequently substituted in the updating equations which yield $x_{1|1}$ and $\Sigma_{1|1}$. In turn, the estimates of the updating equations are substituted back in the prediction equations to obtain $x_{2|1}$ and $\Sigma_{2|1}$. This recursive operation continues until all observations on the measurement vector have been utilized. The prediction errors $\eta_t = y_t - \alpha x_{t|t-1}$, also known as innovations, play a key role in updating the estimator of the state vector in (3.3c). The greater the innovations are the greater the correction in the estimate of $x_{t|t}$ will be. The word filter is hence utilized to indicate that (3.3) is a device that "purifies" the observed values of y_t from the noise they may contain in order to obtain the true state vector x_t. In addition to providing estimates of the unobserved variables in the state vector, Kalman filter provides the means for

estimating the system parameters in ϕ, γ and V based on maximum likelihood principles.

<u>Maximum Likelihood Estimation of the System Parameters</u>. In the classical maximum likelihood approach, a joint probability function is initially specified for T sets of independently and identically distributed random variables $y_1, \ldots, y_T$ as

$$(3.4) \qquad L(y_t, \theta) = \prod_{t=1}^{T} p(y_t),$$

where $p(y_t)$ is the joint density function of the set y_t. For a given set of observed $y_1, \ldots, y_T$, $L(y_t, \theta)$ is explained as the likelihood function which indicates the plausibility of θ given the observed sample.

However, such an approach is not immediately relevant to the measurement vector y_t since its realizations at any period t depend on realizations of previous periods and, thus, are not independent. Instead, the joint probability function for the measurement vector can be specified in terms of its conditional density function as,

$$(3.5) \qquad L(y_t, \theta) = \prod_{t=1}^{T} p(y_t | y_{t-1}, \ldots, y_1).$$

This specification of the joint probability distribution results from the realization that $p(y_1, \ldots, y_T) = p(y_1, \ldots, y_{T-1}) p(y_T | y_1, \ldots, y_{T-1})$, which through repeated substitutions for $t=1, \ldots, T$ yields (3.5).

Since the disturbances v_t in (3.2a) and the initial state x_0 are assumed to be normally distributed, it follows that the conditional distribution of y_t on $y_{t-1}, \ldots, y_1$, is also normal. The mean and the

covariance matrix of this conditional distribution can be readily estimated through the measurement equation (3.2b) and by recognizing that $x_t = x_{t|t-1} + (x_t - x_{t|t-1})$. In particular, the measurement equation can be restated as

$$(3.6) \qquad y_t = \alpha x_{t|t-1} + \alpha(x_t - x_{t|t-1})$$

Taking expectations, the mean and the covariance matrix of the conditional distribution $(y_t|y_{t-1},\ldots,y_1)$ are found to be

$$(3.7a) \qquad y_{t|t-1} = E(y_t|y_{t-1},\ldots,y_1) = \alpha x_{t|t-1}$$

$$(3.7b) \qquad H_t = E(y_t - y_{t|t-1})(y_t - y_{t|t-1})' = \alpha \Sigma_{t|t-1} \alpha' \qquad t=1,\ldots,T$$

Given the normality of the distribution $(y_t|y_{t-1},\ldots,y_1)$ and the results in (3.7), the logarithmic expression of the likelihood function (3.5) will be

$$(3.8a) \quad L(y_t,\theta) = \text{constant} -1/2 \sum_{t=1}^{T} \log|H_t| -1/2 \sum_{t=1}^{T} (y_t - y_{t|t-1})' H_t^{-1} (y_t - y_{t|t-1})$$

or more compactly

$$(3.8b) \qquad L(y_t,\theta) = \text{constant} -1/2 \sum_{t=1}^{T} \log|H_t| -1/2 \sum_{t=1}^{T} \eta_t' H_t^{-1} \eta_t,$$

where η_t are the prediction errors. This form of the likelihood function is often termed the prediction error decomposition form.

For any given parameter vector θ, which includes the system parameters in ϕ, γ, and V, and a given set of observations $y_1,\ldots,y_T$ the Kalman filter provides the values of the innovations η_t and covariance matrix H_t. In this manner, $L(y_t,\theta)$ becomes a function of the parameter

vector ϕ alone. Hence, the likelihood function (3.8) can be maximized with respect to the unknown parameter vector to yield maximum likelihood estimates of the parameters in ϕ, γ, and V. Typically, the maximization is carried out through numerical optimization techniques. When the number of parameters to be estimated is large, efficient algorithms may be necessary and Watson and Engle provide some guidance. Finally, the asymptotic properties of the maximum likelihood estimator in (3.8) under some limiting conditions have been discussed by Pagan.

Initialization of the Filter. To this point, it has been assumed that the initial values of the filter x_0 and Σ_0 are known. In most cases, however, these initial conditions have to be estimated since genuine prior information is rarely available. Chow (1983), discusses a method which can be used to estimate the initial values by utilising the first n observations, n being the number of state variables in the system. Alternative procedures for univariate y_t, which are of interest in this study, are discussed in Harvey and are outlined below.

Theoretically, the initial value of the Kalman filter should be equal to the mean and covariance matrix of the unconditional distribution of the state vector. When the state vector is stationary, its mean is given by $(I-\phi)^{-1}\gamma$ and its covariance matrix is the solution to the equation $\Sigma=\phi\Sigma\phi'$. Equivalently, the initial value of the state vector x_0 may be set equal to zero while the initial value of the covariance matrix Σ_0 is still set equal to Σ.

In the absence of proper priors for $\bar{x}_0$ and Σ_0, non informative or diffuse priors may be employed. For example, setting $\bar{x}_0=0$ and $\Sigma_0=kI$, where k is a large positive scalar and I is the identity matrix, yields a

diffuse prior as $k \to \infty$. The use of a diffuse prior is equivalent to the construction of a proper prior from the first m observations (Harvey). An alternative approach in dealing with the initial conditions in non-stationary models is to regard the initial state vector x_0 as fixed, in which case Σ_0=0. Within this framework, the elements in the vector $\bar{x}_0$ are considered unknown and are estimated as extra parameters in the model.

The particular assumptions made in initializing the Kalman filter have important implications for the choice of the estimation approach and the properties of the estimators. Specifically, alternative likelihood functions may be specified depending on the particular assumptions made about the initial values $\bar{x}_0$ and Σ_0. When proper priors exist for $\tilde{x}_0$ and Σ_0, the Kalman filter generates the so called, exact likelihood function of the observations y through the prediction error decomposition in (3.8). In the absence of proper prior information, a diffuse prior with $\bar{x}_0$=0 and Σ_0=kI may be used to derive the exact likelihood function. Although for large size samples the initial conditions ultimately become unimportant, in cases that the initial conditions appear to have a significant impact on the empirical estimates of the exact likelihood function alternative routes are available. For example, extensions of the Kalman filter which do not depend on the initial conditions may be used to derive the exact likelihood function (Ansley and Kohn).

A parallel initialization procedure is to estimate the initial value of $x_{m+1|m}$ from the first m observations or from a diffuse prior, and set $\Sigma_{m+1|m}$ equal to its steady state value. The steady state value Σ^* of

$\Sigma_{t+1|t}$, can be estimated by running the Riccati equation[1] iteratively until it converges in Σ^*. In this case, an alternative estimator with the same asymptotic distribution as the maximum likelihood estimator in (3.8) can be derived by minimizing the sum of the squared innovations given by

$$(3.9) \qquad S(y_t, \theta) = \sum_{t=m+1}^{T} \eta_t^2 .$$

When Σ_t converges to Σ^* the covariance matrix H_t also converges to its steady state value H^*, it follows that for large samples maximization of (3.8) and minimization of (3.9) will yield approximately the same results.

For a non-stationary state vector it is also possible to assume that the initial state x_0 is constant. Under these conditions, an alternative estimator may be obtained which is not based on the Kalman filter and the prediction error decomposition. By repeated substitution of (3.2a) in (3.2b) a reduced form of the state-space model can be obtained in which y_t is expressed exclusively in terms of the observable x_0, z_t and a complex error structure as,

$$(3.10) \qquad y_t = \alpha\phi^t x_0 + \alpha\gamma \sum_{j=1}^{t} \phi^{t-j} z_j + \alpha \sum_{j=1}^{t} \phi^{t-j} v_j \qquad t=1,..T$$

This system can be estimated through maximum likelihood procedures or alternatively by using the GLS formulation proposed by Rosenberg. A maximum likelihood estimation of (3.10) can be found in Kalaitzandonakes and Shonkwiler.

[1] The Riccati equation is a relationship which may be derived by combining the prediction equation (3.4b) and the updating equation (3.4d) into a single recursion. The Riccati equation then is given by

$$\Sigma_{t+1|t} = \phi(\Sigma_{t|t-1} - \Sigma_{t|t-1}\alpha'(\alpha\Sigma_{t|t-1}\alpha')^{-1}\alpha\Sigma_{t|t-1})\phi' + V$$

Dynamic Properties of Planting Decisions

In modelling dynamic systems, the properties of stability, and controllability, contribute meaningful information about the dynamic behavior of the systems. Empirical investigation of these properties in the case of Florida citrus planting decisions is useful not only in describing the dynamics of the system but also in policy analysis. The properties of stability, and controllability, are reviewed below within the framework of a deterministic state space model, such as the one resulting from (3.2) when v_t is ignored.

Loosely speaking, stability refers to the ability of a dynamic system to return to its equilibrium position following a small displacement. In the absence of analytical conditions for the existence of a steady state in Florida citrus planting activities, it is even more important to explore their stability properties. The stability of the deterministic system (3.2) can be decided by estimating the eigenvalues of the transition matrix ϕ. Specifically, a necessary and sufficient condition for stability, is that the characteristic roots of ϕ have modulus less than one (Chow 1975).

The property of controllability arises when the feasibility of specific time paths using possible instruments is investigated. A deterministic system as in (3.2), is said to be (completely) controllable if for each pair of states x_0 and x^*_t there exists a feasible instrument vector w which allows the system to move from x_0 to x^*_t in a finite time interval. The policy implications of such property for Florida citrus planting investments are apparent. Through the property of controllability it may be possible to provide some evidence as to whether

a set of economic instruments, such as subsidies or taxes, may be used to direct the productive tree stock from some initial level to a target level within a specific time period.

The condition for controllability of a dynamic system within the state-space framework becomes a matrix rank qualification. This condition can be derived as follows. Successive substitutions of (3.2e) into itself gives

(3.11a) $$x_t = \phi^t x_0 + \gamma \sum_{j=0}^{t-1} \phi^{t-j} z_j \qquad t=1,\ldots,T.$$

or more compactly

(3.11b) $$x_t = \phi^t x_0 + Q_t z^t$$

where $Q_t=[\phi^{t-1}\gamma,\phi^{t-2}\gamma,\ldots,\phi\gamma,\gamma]$ and $z^t=[z_0,z_1,\ldots,z_{t-1}]'$. Controllability of the system then is concerned with the existence of solutions to the algebraic system

(3.12) $$x^*_t - \phi^t x_0 = Q_t z^t$$

If a solution to (3.14) exists, the matrix $[\phi^{n-1}\gamma,\ldots,\phi\gamma,\gamma]$ must have rank n, where n is the number of state variables (Aoki).

The conditions of stability and controllability have been extended for stochastic dynamic systems. To a large extent, the deterministic conditions remain applicable in the stochastic framework. For a stochastic system stability is still determined through the properties of

the transition matrix ϕ (Chow 1975). Furthermore the deterministic concept of controllability remains valid, only the deterministic conditions are replaced with probabilistic statements (Conners).

Concluding Comments

The developments in section two illustrated that the dynamic unobserved components model satisfies the requirements for an appropriate structural model of Florida citrus plantings. The unobserved new plantings and replantings are explicitly and separately considered in the structural relationships (3.2e). However, the proposed model not only allows estimation of planting decisions in the absence of detailed data, but it also includes direct structural estimation procedures when such information is accessible, as a special case.

Aoki has demonstrated that a great variety of dynamic systems, including linearized approximations of nonlinear systems and reduced form dynamic systems, can be transformed into the standard state-space form. Moreover, in terms of statistical specification the state-space model is also inclusive of a large number of econometric models. Watson and Engle have shown that linear regressions, integrated autoregressive-moving average time series models (ARIMA), time varying coefficient regressions, and a number of unobserved components models are all special cases of the state-space model.

In structural models of perennial supply response linear forms are usually employed to represent planting and cultivation relationships. These linear systems are often justified as approximations to the true underlying dynamic supply systems of perennial supply. Since such linear

systems could be transformed in the standard state-space form, they can be seen as a special case of the state-space model. In addition, when detailed data allow direct structural estimation of such models, the more general Kalman filter approach could also be used as a substitute for ordinary least squares procedures under certain circumstances. For example, if price elasticities in perennial supply response are in fact non-stationary (Trivedi, Akiyama and Trivedi), the Kalman filter may be used to estimate and test for time varying price coefficients (Garbade). Furthermore, Kalman filter is a preferable estimation procedure over ordinary least squares in the presence of multicollinearity in the design matrix (Watson).

CHAPTER IV
EMPIRICAL SPECIFICATIONS AND RESULTS

Introduction

Considerations in previous chapters have demonstrated that the annual output of the Florida citrus industry can be varied in the short run through adjustments in the variable input utilization rates and in the long run through new plantings and replantings. In analyzing the structures of acreage and supply response of Florida citrus, it is of interest to associate such short and long run adjustments to changing economic conditions.

The insights gained through the preceding developments are utilized in this chapter to specify theoretically consistent and empirically relevant structural relationships for cultivation and planting activities of Florida citrus. The particular empirical specifications of the cultivation and planting relationships to be estimated are presented in section two. Econometric estimation of these relationships necessitates the transformation of unobserved price expectations, which enter both the cultivation and planting decisions, into estimable forms. The principle of economically rational expectations (Feige and Pierce) is employed to characterize the price expectations of Florida citrus growers. The underlying assumptions in constructing economically rational expectations from observed price series of various Florida citrus varieties are also discussed in section two. The estimation procedures and the empirical

results for Florida citrus planting and cultivation decisions are presented in section three

Econometric Modeling Considerations

Planting Relationships Theoretical considerations in the firm's optimization problem (2.8) and (2.9) provided some guidance with regard to the variables which may be important in explaining Florida citrus replanting and new planting investments For new plantings, the derived optimality conditions suggest that the firm invests in new citrus trees up to the point that the stream of discounted net revenues acquired over the productive life of the stock compensates the initial investment for the establishment of the grove Hence the firm must take into account output prices and production costs in appraising the flow of net revenues, and the costs of land and capital in evaluating the initial investment The optimality conditions further indicate that new planting investment in any given period depends on the tree stock of the previous period which constitutes the initial condition for the firm's optimal control problem In addition, the optimality conditions imply that the firm's new planting decisions in any given period are influenced by new planting and replanting decisions in the previous period

Several perennial supply response studies (French and Mathews, and French et al.) have postulated supply relationships in which the expected price of alternative crops affect the perennial planting decisions Such specifications can be justified on the basis of a semi-Marshallian

derivation of the supply function rather than the Marshallian[1] derivation offered in (2.8) and (2.9). Florida oranges and grapefruit compete for land and financial resources and it is reasonable to assume that the expected price of one may be considered as an appropriate opportunity costs for the other by the Florida citrus growers.

Based on the above considerations, it appears that changes in real expected prices, production costs, investment costs, opportunity costs, previous period tree stock, and past new plantings and replantings could potentially influence new planting activities of Florida citrus. A complete time series on establishment costs for Florida citrus groves, however, is not available. To overcome this constraint, it is assumed that production and investment costs have moved in a parallel manner over the period of interest. Thus, variations in expected prices and production costs are assumed to sufficiently approximate changes in the expected profitability of Florida citrus.

Replantings of Florida citrus are mainly undertaken to replace trees damaged by pests and diseases as well as tree-killing freezes. Tree losses from diseases and pest infestations are considered to be proportional to the existing tree stock in any given season. However, the rate of proportionality is neither assumed to be constant over time nor

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[1] The two ends of the spectrum in deriving supply functions are the Walrasian and the Marshallian specifications. The Walrasian specification results from a general equilibrium model and the derived supply function depends on the prices of all commodities considered in the model. The Marshallian specification results from a partial equilibrium setting, which presumes that all other commodity markets are in equilibrium, and the supply function of a particular commodity depends only on its own price. In the case that two commodities are simultaneously considered while all other markets are assumed in equilibrium, the derived supply function has the prices of both commodities as arguments and is termed quasi-Marshallian.

known. Hence the tree stock of previous periods along with one periodic freeze occurrences appear to be important influences in generating replanting activity.

From the firm's optimization problem and the derived optimality conditions it may be inferred that replantings of Florida citrus are myopic economic decisions. The direct costs of replantings are minimal relative to the expected revenue flows that the resets would generate over their productive life cycle. Thus, long term price expectations are not expected to significantly influence the replanting decisions of the Florida citrus firm. Costs of adjustment and, in some cases, availability of young trees appear to be the most important factors in delaying replantings of Florida citrus. In particular, fixed costs of "pushing" dead trees out of the grove as well as costs incurred due to special cultural practices required for the resets induce firms to replant every two or even three years so that fixed costs are allocated among a greater number of trees. Finally, the optimality conditions suggest that, as with new plantings, replantings are influenced by previous period replanting and new planting decisions.

Having identified the factors which are theoretically expected to affect planting decisions of Florida citrus, structural relationships to be empirically estimated may be specified for new plantings and replantings. Some care, however, must be taken in the econometric design of the empirical model in preserving degrees of freedom as only twenty-two observations are available for the estimation. A parsimonious specification of Florida citrus new planting and replanting investments cast within the framework of the dynamic unobserved components model, is given by

(4.1a)
$$\begin{bmatrix} r_t \\ n_t \end{bmatrix} = \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} \begin{bmatrix} r_{t-1} \\ n_{t-1} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & 0 & 0 \\ 0 & 0 & \gamma_{22} & \gamma_{23} \end{bmatrix} \begin{bmatrix} w_t \\ c_t \\ p^*_t \\ p^\circ_t \end{bmatrix} + \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix}$$

(4.1b)
$$y_t = [1\ 1] \begin{bmatrix} r_t \\ n_t \end{bmatrix}$$

In specification (4.1), real prices are constructed as the ratio of nominal price to production costs. Prices p^*_t and p°_t denote the expected real price of Florida citrus and the expected real opportunity cost respectively, and are assumed to affect only the new planting decisions. The variable w_t is an index of freeze severity based on estimated freeze-induced losses of Florida citrus trees while c_t represents replanting costs and are considered to influence only the replanting decisions. Actual total plantings y_t are normalized by the previous period total tree stock and subsequently multiplied by one hundred. Thus, replantings and new plantings are expressed as percentages of the previous period tree stock.

Output Relationships. In examining cultivation decisions for Florida citrus, it is of interest to specify structural relationships which explain short run output adjustments performed in response to economic stimuli. The empirical specifications of such output relationships employed here follow theoretical developments introduced by Trivedi and Akiyama and Trivedi.

Assuming the existence of an average age-yield profile, total feasible output $Q^F(t)$ is defined as

$$Q^f(t) = \sum_{v} \mu(v)\, h(t,v) \qquad v \in V_m \tag{4.2}$$

where $\mu(v)$ denotes the average age-yield profile. Hence, feasible output is completely determined by the existing capital stock and its age distribution in any given period.

A solution to the optimization problem of the Florida citrus firm would imply that for any given time path of expected prices and costs there exists a profit maximizing path of variable input levels and associated set of vintages. These capital and "labor" input levels would in turn imply a profit maximizing level of output defined as planned output $QP(t)$. The firm attempts to attain this profit maximizing level of output in every given period through both short run and long run output adjustments. New planting and replanting activities performed in period T target output adjustments in period T+L and thereafter due to the gestation and full production lags present in Florida citrus cultivation. The profit maximizing output levels for period T+L as perceived by the firm in periods T and T+L-1 would coincide only if the original expectations of the firm were fully realized. If the firm's expectations shaped at time T diverge from actual prices and costs realized in the market L-1 periods latter, the firm will attempt to maximize the quasi-rents of the fixed factors in period T+L-1 by adjusting the variable input utilization levels. Such short run output adjustments are conditional on the existing tree stock and its age distribution.

Based on these considerations, it may be assumed that the actual

output of the firm in any given period will deviate from planned output due to the divergence of the actual and expected prices as

$$(4.3)\qquad \frac{Q(t)}{Q^{p}(t)} = H\left[\frac{p(t)}{p^{e}(t)}\right] + u(t),$$

where H is some unknown function and u represents the unexplained portion of the deviation between $Q(t)$ and $Q^{p}(t)$. This unexplained portion includes stochastic output shocks due to weather variations and pest infestations as well as productivity gains due to technical change. Utilizing the result in (4.3) and given that the relationship $Q(t)=Q^{p}(t)[Q(t)/Q^{p}(t)]$ holds as an identity, allows actual output to be re-written as

$$(4.4)\qquad Q(t) = Q^{p}(t)\; H\left[\frac{p(t)}{p^{e}(t)}\right] + u(t)$$

Since mature vintages $k(t,v)$ represent optimal long term output adjustments of the firm in previous periods, planned output would equal feasible output in any given period if the average yield-age profile $\rho(v)$ remained unaffected by short run output adjustments. However, the yields in any given period may be influenced by previous period variable input utilization levels, such as fertilizer applications. Hence, the relationship between planned and feasible output may be described as

$$(4.5)\qquad \frac{Q^{p}(t)}{Q^{f}(t)} = G\,(p(t-1), \ldots, p(t-s)) + e(t),$$

where prices $p(t-1), \ldots, p(t-s)$ denote the dependence of current yields on past input utilization levels, and $e(t)$ represents random disturbances. Since $Q^{p}(t)=Q^{f}(t)[Q^{p}(t)/Q^{f}(t)]$ holds by definition, $Q^{p}(t)$ may be expressed as

$$(4.6) \qquad Q^p(t) = Q^f(t)\ G\ (p(t-1), \ldots, p(t-s)) + e(t)$$

Substituting (4.6) into (4.4) yields

$$(4.7) \qquad Q(t) = Q^f(t)\ F\ [(\frac{p(t)}{p^*(t)}), p(t-1), \ldots, p(t-s)] + v(t)$$

These substitutions allow actual output to be expressed in terms of the observable $Q^f(t)$ rather than the unobserved $Q^p(t)$.

Input-output substitution possibilities may vary across different vintages and hence short run output adjustments may also vary from one vintage to another. Therefore, separate output relationships, such as in (4.7), must be specified for various vintages of Florida citrus. A categorization of Florida citrus bearing vintages that allows sufficient differentiation among them includes the following four age classes of bearing trees: (a) four to nine year old (b) ten to fourteen year old (c) fifteen to twenty-four year old and (d) over twenty-five year old.

Assuming that linear relationships can adequately approximate the unknown function F( ) in (4.7), the output relationships to be empirically estimated are specified as

$$(4.8) \qquad \frac{Q_{t,v}}{Q^f_{t,v}} = \alpha_0 + \alpha_1 W_t + \alpha_2 T_t + \alpha_3 \frac{p_{t-1}}{p^*_{t-1}} + \alpha_4 p_{t-2} + \varepsilon_t,$$

where $Q_{t,v}$ denotes actual output of vintage v at period t while $Q^f_{t,v}$ represents feasible output of vintage v at period t and it is derived from a given average age-yield profile and the actual age distribution of citrus tree stock at time t. The variable W_t is a weather dummy variable reflecting output reductions from random freeze occurrences. The trend

variable T_t is included in (4.8) to capture possible productivity gains over time. The price ratio p_{t-1}/P^{*}_{t-1} is used to represent the effects of the deviations of actual prices from expected prices on the short run output adjustments of the firm. Lagged prices p_{t-2} allow for possible effects of past input utilization levels on current yields. All the prices in the above specification are derived as the ratio of actual price to production costs.

<u>Price Expectations</u>. Present in both the planting relationships (4.1) and output relationships (4.8) are price expectations formed by the Florida citrus firms. However, such price expectations are not directly observable by the economic analyst. A common approach in empirically evaluating price expectations is to employ a proxy or a model of expectation formation.

Various price expectation models have been utilized in the perennial supply literature with most common being adaptive expectations or some similar autoregressive scheme. The ad hoc nature of these expectational forms is generally considered an important limitation. However, theoretically consistent rational expectations, which are the forecasts from an appropriate economic model that the firms may employ, have rarely been used in empirical supply response studies since they imply extensive informational requirements and complex supply structures.

With regard to rational expectations, Feige and Pearce noted that although theoretically consistent they overlook the probable costs of obtaining the necessary information. The authors suggested that firms will take into account the tradeoffs between the benefits from additional information in forming forecasts and the implied costs. Feige and Pearce

suggested an alternative approach to expectation formation which emphasizes the efficient use of readily available information. The proposed economically rational expectations provide a middle ground between rational expectations and ad hoc specifications.

Within the framework of economically rational expectations, Florida citrus firms are expected to utilize readily accessible information in forming price forecasts. One relative inexpensive approach in obtaining forecasts of future Florida citrus prices is to consider the information contained in the series of past prices.

Identifying and estimating an efficient forecasting model for a given time series requires the modeling of the stochastic process underlying the time series of interest. Box and Jenkins have proposed an approach for such modeling, which uses the autocorrelation and partial autocorrelation functions of the series to provide guidance. After an appropriate model has been estimated, its overall adequacy can be tested by the Q statistic (Fiege and Pierce) which may be calculated as follows

$$Q = N \sum_{s=1}^{T} r_s^2(e_t), \tag{4.9}$$

where N denotes the number of data observations and $r_s(e_t)$ represents the estimated autocorrelation coefficient of the innovations e_t and e_{t-s}. The Q statistic follows a chi-square distribution with T-p-q degrees of freedom, where p is the order of the autoregressive process and q is the order of the moving average process of the estimated model. In the case that the estimated value of Q exceeds the appropriate chi-square tabular value the model is considered inadequate.

Following the above procedures, the stochastic processes underlying the price series of Florida late oranges, early-midseason oranges, and total oranges, white grapefruit, colored grapefruit, and total grapefruit were investigated. It was found that the expected real prices of late, early-midseason, and total oranges can be modeled by autoregressive processes of order four. A Langrange multiplier test of the hypothesis that all lags are equally weighted yielded chi-square statistics of 9.18 for total oranges, 8.84 for early-midseason oranges, and 8.92 for late oranges with four degrees of freedom. Hence, the above hypotheses could not be rejected at the .05 level and the use of lagged four-year price averages were regarded consistent expected prices for late, early-midseason and total oranges. In a similar manner, it was found that the expected real price of Florida white, colored, and total grapefruit can be represented by autoregressive processes of order three. A Langrange multiplier test of the hypotheses that the coefficients of the lags were each 1/3 yielded chi-square statistics of 6.99 for total grapefruit, 5.32 for colored grapefruit, and 7.37 for white grapefruit with three degrees of freedom. Thus, the hypotheses could not be rejected at the .05 level and the use of lagged three year price averages were considered appropriate expected prices for white, colored, and total grapefruit.

The overall adequacy of the estimated models of price expectations were tested through Q statistics calculated according to (4.9). Autocorrelation for innovations up to eight periods apart (ie T=8) were considered in evaluating the Q statistics for all estimated models. The Q statistics for total, early midseason, and late oranges were found to be 4.81, 5.96, and 2.90 respectively and hence lower than the tabular value

of a chi-square distribution with four degrees of freedom at the .05 level. In a similar manner, the Q statistics for total, white, and colored grapefruit were found to be 1.25, 1.45, and 1.28 respectively and consequently lower than the tabular value of a chi-square distribution with five degrees of freedom at the .05 level. Thus, the derived models of expected real prices of Florida citrus were regarded as adequate representations of the underlying stochastic process and consistent with the principle of economically rational expectations.

Empirical Results

Planting Relationships. Estimation of replanting and new planting investment of various citrus varieties within the specification (4.1) can be accomplished with various estimators discussed in chapter three. Estimators (3.8), (3.9), and (3.10) were initially employed to estimate new plantings and replantings for all citrus varieties of interest. One regularity observed in all estimated models was the stationarity of the Kalman filter which converged to its steady state exponentially fast. This implied that the estimators (3.8) and (3.9) could be considered approximately equivalent. However, estimator (3.9) appeared more robust, converged faster, and unlike the maximum likelihood estimator (3.8) its ability to converge exhibited little sensitivity to the initial parameter values used to initialize the algorithm. Investigation with suitable experimental data allowed further comparisons among the three estimators. Overall, estimator (3.9) provided parameter estimates closer to the true parameter values and exhibited less sensitivity to the initial parameter values supplied to the algorithms. Based on these qualifications

estimator (3.9) was utilized in estimating the new planting and replanting relationships of Florida citrus presented in this study.

Estimation of (4.1) by minimizing the sum of squared innovations as in (3.9), requires initialization of the Kalman filter with the values of $\bar{x}_0$ and Σ_0. With regard to the initial value of the state vector x_0, an informed prior was assumed available. Specifically, the initial values of n_0 and r_0 were arbitrarily set equal to two thirds and one third of the known value of y_0, across all citrus varieties. Given that the sample data begins in the 1966-67 season, the above allocation implies that new plantings accounted for two thirds of the total plantings during the 1965-66 season while the rest was replacement investment. This is consistent with the fact that the Florida citrus industry experienced substantial growth during the late 1960s.

For the initialization of the covariance matrix Σ_0 two different approaches were initially attempted. First, Σ_0 was specified according to a diffuse prior kI, where k is a large integer, and second Σ_0 was set equal to its steady state value Σ^* iteratively derived through the Riccati equation. Since both approaches yielded similar results, the simpler diffuse prior Σ_0=kI was employed in the final derivations.

Based on these considerations, new planting and replanting relationships specified according to (4.1) were estimated for late, early-midseason, and total oranges, as well as white, colored, and total grapefruit over the period 1966-67 to 1987-88. Time series data on plantings, total tree stock, prices, costs, and calculated freeze-induced tree losses were utilized for the estimations. These data are presented and discussed in Appendix A. In the initial estimation of the planting

relationships, replanting costs c_t were found to have, contrary to a priori expectations, a positive sign and to be not statistically different from zero across all citrus varieties. For these reasons, replanting costs were dropped from the specifications of replanting investment and the models were re-estimated.

The empirical relevance and validity of the estimated Florida citrus planting relationships are evaluated in several different ways. First, the overall efficiency of the estimated models in explaining the variability of the observed data is evaluated. A measure of fit, R^2, parameter standard errors, and a measure of first order residual autocorrelation ρ are derived from the estimated innovations in y_t. In addition, the projected total plantings obtained from the estimated models are compared to the actual total plantings in order to identify the ability of the models to capture the year to year variation in the observed series. The plausibility of the calculated values of the unobserved new plantings and replantings are also evaluated. Although no conclusive method could be identified for testing the accuracy of the projected unobserved components, several different criteria are utilized in evaluating them. For example, in cases where new plantings are implied by the estimated models, a parallel net growth in the bearing tree stock after a four year gestation period is anticipated. Such patterns, however, are valid only for periods where the bearing tree stock has remained unaffected by major tree killing freezes.

Second, the dynamic unobserved components specification of planting relationships are evaluated by comparing them to a single equation reduced form specification of Florida citrus total plantings. A model which has

been frequently used in perennial crop supply analysis is the Nerlovian partial adjustment model (Askari and Cummings). If total plantings of Florida citrus y_t were consistent with the partial adjustment hypothesis, total plantings could be specified as

(4.10a) $$y_t - y_{t-1} = b\ (y^*_t - y_{t-1})$$

(4.10b) $$y^*_t = a_0 + a_1\ w_t + a_2\ p^e_t + a_3\ p^c_t + e_t$$

where y^*_t denotes the "desired" level of total plantings towards which actual plantings y_t adjust in any given period, b is the adaptation coefficient, and e_t represents random disturbances. The desired level of total plantings is assumed to be a linear function of expected prices p^e_t, opportunity costs p^c_t, and the index w_t representing freeze-induced tree losses. Price expectations are still considered to be consistent with the hypothesis of economically rational expectations. Substitution of (4.10b) into (4.10a) results in a single equation reduced form specification as

(4.11) $$y_t = \alpha_0 + \alpha_1\ y_{t-1} + \alpha_2\ w_t + \alpha_3\ p^e_t + \alpha_4\ p^c_t + u_t$$

where $\alpha_0 = ba_0$, $\alpha_1 = 1-b$, $\alpha_2 = ba_1$, $\alpha_3 = ba_2$, and $\alpha_4 = ba_3$. The single equation reduced form models of Florida citrus plantings were estimated using ordinary least squares, over the period 1966-67 to 1987-88.

Late oranges. Planting activities for Florida late oranges were examined within the framework of the dynamic unobserved components specification (4.1) and the estimated parameters of one planting and replanting relationships are reported in Table 4.1. The estimated coefficients ϕ_{12} and ϕ_{21} are not statistically different from zero and

Table 4.1 Structural Parameter Estimates of Late Orange Plantings, 1966-67 to 1987-88.

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.859	0.046
ϕ_{12}	0.063	0.098
ϕ_{21}	-0.080	0.140
ϕ_{22}	0.082	0.158
γ_{11}	0.385	0.053
γ_{21}	0.320	0.147
γ_{22}	-0.306	0.114

$R^2 = 0.931$
$\rho = -0.154$

Table 4.2 Reduced Form Parameter Estimates of Tree Plantings: Late Oranges, 1966-67 to 1987-88.

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	-0.069	1.890
α_1	0.668	0.224
α_2	0.383	0.068
α_3	0.175	0.214
α_4	-0.150	0.148

$R^2 = 0.894$
$\rho = -0.485$

hence the hypothesis that replantings and new plantings are dynamically interdependent is not supported within the framework of late oranges.

Expected real prices of late oranges were found to have significant positive effects on new plantings as denoted by parameter estimate γ_{22}. Furthermore opportunity costs, represented by the expected real price of total grapefruit, were found to have significant negative effects on late orange new plantings as indicated by the parameter estimate γ_{23}. These findings suggest that growers engage in new plantings of late oranges when their relative profitability is expected to increase. Early-midseason expected prices were also tried as alternative opportunity costs to late oranges. However, the prices of the two orange varieties have moved parallel to each other over time causing multicollinearity problems in estimation.

Consistent with a priori expectations are the effects of tree-killing freezes on replantings. Specifically, freeze-induced tree losses were found to generate significant replanting activity measured by the parameter estimate γ_{11}. The weather variable w_t which measures the effects of such losses on replanting activities entered the model with a three year lag. However, weighted averages of the tree losses with two and three year lags performed similarly.

Several different lag structures were attempted in specifying the effect of tree-killing freezes on late orange replantings, since several factors indicated that losses induced by a freeze in any given season would likely affect replantings for several subsequent periods. At the firm level, cash flow constraints resulting from revenue losses following a freeze as well as credit restrictions often force the firm to replant

the damaged trees with some lag At the aggregate level, availability of young trees for resets have in many cases restrained immediate replacements of the damaged trees Specifically, the regular nursery stock is usually not sufficient to satisfy the excess demand for young trees following distructive freezes In the early 1980s, widespread canker infestations of young trees in Florida nurseries induced additional problems of reset availability.

The overall adequacy of the estimated model in explaining the variation of late orange planting activities is illustrated in Figure 4 1, where both the actual total plantings of late oranges and those projected by the estimated model are pictured The estimated model appears to have traced the observed late orange plantings fairly closely over the period of interest. In addition, the model has adequately captured the escalated plantings in late oranges in the last two seasons considered in this analysis As depicted in Figure 4 3, a large portion of these plantings is regarded as replanting activity directed towards replacing trees damaged by the sequential freezes which occurred between 1983-84 and 1985-86

New plantings derived from the estimated model are illustrated in Figure 4 2. The estimated model indicates that minimal new plantings occurred in the 1970s while new investment grew at an average annual rate of almost 1 5 percent of the existing tree stock in the late 1960s and in the 1980s Such findings appear in agreement with the investment behavior of the Florida late orange producers implied by the estimated model. Specifically, the period of limited new plantings coincides with the

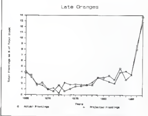

Figure 4 1 Comparisons of Actual and Projected Plantings of Late Oranges 1966 67 to 1987 88

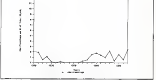

Figure 4 2 Estimated New Plantings of Late Oranges

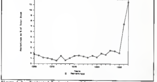

Figure 4 3 Estimated Replantings of Late Oranges

period of low prices experienced by the late orange industry in the 1970s. In contrast, during periods of higher prices new investment is also present.

The dynamic properties of the estimated system of new plantings and replantings were investigated and within this framework the characteristic roots of the estimated ϕ matrix were found to be real and equal to 0.865 and 0.075. Since both roots lie within the unit circle, it was concluded that the estimated plantings system of late oranges is dynamically stable. In addition, the rank of the matrix $[\phi\gamma,\gamma]$ was examined in order to assess the controllability of the estimated system. The matrix $[\phi\gamma,\gamma]$ was found to have full rank equal to two and hence some evidence is provided that policy instruments could be used to direct the productive stock of the industry towards a desired level, in case that such objectives were of interest.

A single equation reduced form model of late orange plantings was also estimated according to specification (4.11) and the derived results are presented in Table 4.2. The results indicate that the explanatory power of dynamic unobserved specification is greater than that of the reduced form specification. Furthermore, the estimated autocorrelation coefficients suggest that the estimated errors in the reduced form specification exhibit some serial correlation not present in the estimated disturbances of the structural specification. More important, however, are the different implications of the two specifications on the price responsiveness of late orange producers. Contrary to the derived results in the structural specification of late orange planting activities, an

statistically significant correlation between plantings and expected prices could be identified in the reduced form model.

Early-midseason oranges. Planting decisions for early-midseason oranges were examined within the framework of the structural specification (4.1) and the estimated coefficients of new planting and replanting activities are displayed in Table 4.3. Parameter estimates of ϕ_{12} and ϕ_{21} have been omitted from the presented coefficients. In the unrestricted model, the t-values associated with these two parameters were less than 0.25 and hence their values were restricted to zero and the model was re-estimated.

As with late oranges, new plantings of early-midseason oranges were found to be positively related with expected real prices and negatively with opportunity costs. Thus, it may be concluded that early-midseason orange growers act in an economically consistent manner and engage in new plantings in periods of high expected prices and profits. This implies that, ceteris paribus, in periods of high prices some net growth in the producing tree stock of the early-midseason orange industry should be expected.

Tree losses caused by freezes were found to induce greater replanting activity for early-midseason oranges. The weather variable a_t, measured tree losses lagged by three years. However, weighted averages with tree losses lagged by two and three years yielded comparable results.

Actual plantings were compared to the planting levels implied by the estimated model in order to appraise its ability to explain the year to year observed variations. The actual and predicted values of early-midseason plantings are pictured in Figure 4.4. With the exception of the

Table 4.3. Structural Parameter Estimates of Early-Midseason Orange Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.966	0.047
ϕ_{22}	0.310	0.094
γ_{11}	0.325	0.042
γ_{22}	0.216	0.121
γ_{23}	-0.229	0.101

$R^2 = 0.902$
$\rho = -0.108$

Table 4.4. Reduced Form Parameter Estimates of Early-Midseason Orange Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	0.185	2.105
α_1	0.381	0.190
α_2	0.475	0.078
α_3	0.357	0.262
α_4	-0.257	0.183

$R^2 = 0.890$
$\rho = -0.251$

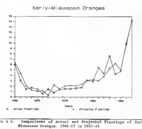

Figure 4.4. Comparisons of Actual and Projected Plantings of Early-Midseason Oranges, 1966-67 to 1987-88

three year period 1981-82 to 1984-85, the estimated model appears able to explain a substantial part of the observed fluctuations in early-midseason plantings over the period 1966-67 to 1987-88. Furthermore, the estimated model has closely traced the increased planting rates in the 1986-87 and 1987-88 seasons. As with late oranges, a large portion of the heavy plantings observed in the last two seasons was attributed by the estimated model to increased replanting activity which is depicted in Figure 4.6.

New plantings obtained from the estimated model are pictured in Figure 4.5. New planting activity was rather insignificant over the 1970s while some new investment was found in the late 1960s and in the 1980s at a average annual rate of almost two percent of the total tree stock. The plausibility of the estimated rates of new plantings was indirectly examined by analyzing the net growth in the early-midseason bearing tree stock. Such indirect approach was utilized to consider net growth of bearing acreage until the 1979-80 season due to the fact that subsequent tree killing freezes did not allow such regularities to be identified. However, for the period that such comparisons were possible it was found that new plantings and net growth in the bearing tree stock four years later followed comparable trends.

The dynamic stability of the estimated early-midseason planting system may be readily identified. Since $\phi_{12}=\phi_{21}=0$, the characteristic roots of the ϕ matrix are equal to $\phi_{11}=0.966$ and $\phi_{22}=0.310$ respectively. Hence, since both roots lie within the unit circle it is concluded that the system is dynamically stable. The dynamic estimated system was also determined to be controllable since the rank of the matrix $[\phi\gamma,\gamma]$ was found to be equal to two.

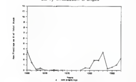

Figure 4 5 Estimated New Plantings of Early-Midseason Oranges

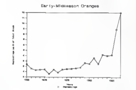

Figure 4 6 Estimated Replantings of Early-Midseason Oranges

A single reduced form specification of early-midseason orange plantings was estimated and the derived parameter estimates are presented in Table 4.4. As with late oranges, the structural model of early-midseason orange plantings compares favorably with the reduced form specification in terms of explanatory power and statistical significance of the estimated coefficients.

Total oranges. Planting activities for total oranges were investigated within the framework of a dynamic unobserved components structural model and the estimated parameters are reported in Table 4.5. Some evidence of dynamic interdependence between new planting and replanting investments is provided by the estimated model of total orange plantings although such evidence could not be identified for the separate orange varieties. The estimated coefficient ϕ_{21} was statistically different from zero and negative suggesting that previous replanting activity crowds out new investment. Hence, high rates of replantings which increase the expected future productive capacity of the total orange industry are likely to discourage new investors from entering the industry. The estimated coefficient ϕ_{12} was not statistically different from zero and therefore an influence from new plantings on replantings could not be supported.

Expected real prices were found to have positive and statistically significant effects on Florida orange new plantings. Opportunity costs, represented by the expected price of total grapefruit, were determined to have negative and statistically significant influence on new plantings. In addition, tree losses caused by freezes were found to have a positive and significant effect on replanting activity of total oranges while, an

Table 4.5 Structural Parameter Estimates of Total Orange Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.923	0.050
ϕ_{12}	-0.065	0.060
ϕ_{21}	-0.236	0.129
ϕ_{22}	0.221	0.093
γ_{11}	0.401	0.040
γ_{22}	0.339	0.116
γ_{23}	0.280	0.088

$R^2 = 0.934$
$\rho = -0.243$

Table 4.6 Reduced Form Parameter Estimates of Total Orange Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	-0.073	1.910
α_1	0.493	0.198
α_2	0.439	0.072
α_3	0.296	0.231
α_4	-0.212	0.160

$R^2 = 0.903$
$\rho = 0.442$

previously w_t entered the replanting equation with a three year lag. These findings are in agreement with the influences identified for the separate orange varieties.

Actual and predicted plantings calculated from the estimated model are illustrated in Figure 4.7. As with late and early-midseason oranges, the estimated model was found to adequately account for the observed variation in actual plantings of total oranges. The new plantings and replantings implied by the estimated model are depicted in Figures 4.8, and 4.9 respectively. The derived rates of new plantings and replantings are in agreement with the new planting and replanting series obtained from the late and early-midseason orange models. The estimated model implies minimal new planting investment in the 1970s and an annual average rate of two percent of the existing stock in the late 1960s and the 1980s. In addition, new plantings and replantings estimated for early and midseason oranges add up to the calculated plantings of total oranges. The consistency of the projected new plantings and replantings across the separate varieties and their aggregate lends additional credibility to the estimated models.

The dynamic stability of the estimated model was examined by calculating the characteristic roots of the transition matrix ϕ. The roots of ϕ were found to be real and equal to 0.945 and 0.193. Since both roots lie within the unit circle the system was determined dynamically stable. As with early and midseason oranges, the estimating structural system of total orange plantings was also found to be controllable since the matrix $[\phi\gamma,\gamma]$ was found to be of full rank.

A reduced form specification of total oranges was estimated and the

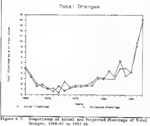

Figure 4 7. Comparisons of Actual and Projected Plantings of Total Oranges, 1966-67 to 1987 66

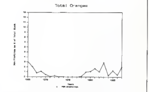

Figure 4 8 Estimated New Plantings of Total Oranges

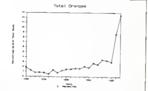

Figure 4 9 Estimated Replantings of Total Oranges

derived parameter estimates are presented in Table 4.6. The results indicate that the explanatory power of the reduced form is lower than that of the structural specification. Furthermore, although the estimated coefficients of the expected price and opportunity costs are comparable in the two estimated models, the statistical significance levels of these coefficients were quite lower in the reduced form specification. Finally, the estimated autocorrelation coefficient of the reduced specification indicates that a possible serial correlation problem may be present in this specification. Overall, it may be concluded that the structural form specification of total orange planting activities performed better than the reduced form specification.

From the derived empirical results, it may be deduced that the economic structure of planting activities in the Florida early and midseason orange industries are similar. Furthermore, the estimated structure of planting activities of total oranges was found parallel to those of the separate varieties and hence no distortions due to aggregation were inferred.

White grapefruit. Planting activities for Florida white grapefruit were investigated within the framework of the dynamic unobserved components specification (4.1) and the derived results are shown in Table 4.7. The estimated coefficients of ϕ_{12} and ϕ_{21} are statistically different than zero supporting the hypothesis that replantings and new plantings are dynamically interdependent.

The results further imply that expected real prices of white grapefruit have statistically significant positive influence on new planting investment. In addition, opportunity costs represented by the

Table 4.7 Structural Parameter Estimates of White Grapefruit Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.373	0.220
ϕ_{12}	0.485	0.073
ϕ_{21}	-0.137	0.071
ϕ_{22}	0.577	0.157
γ_{11}	0.110	0.079
γ_{22}	0.146	0.035
γ_{23}	-0.055	0.021

$R^2 = 0.940$
$\rho = -0.302$

Table 4.8 Reduced Form Parameter Estimates of White Grapefruit Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	-2.105	2.020
α_1	0.581	0.078
α_2	0.069	0.082
α_3	0.187	0.140
α_4	0.182	0.217

$R^2 = 0.806$
$\rho = -0.229$

expected real price of total oranges were found to have statistically significant negative effects on new plantings. The expected real price of colored grapefruit was also utilized as possible opportunity costs to white grapefruit investment but performed less satisfactory. Hence, white grapefruit growers undertake new planting investment when the relative profitability of white grapefruit is expected to increase.

The estimated coefficient of γ_{11} which indicates the effect of tree-killing freezes on replantings was positive but not statistically significant. The weather variable w_t which measures the effects of estimated tree losses due to freezes was, as in previous cases, specified with a three year lag. Other lag structures were attempted but with less satisfactory results.

The overall adequacy of the estimated model in explaining planting activities of white grapefruit is depicted in Figure 4.10, where both the actual and predicted plantings are pictured. The estimated model appears to have closely traced the observed planting levels with an exception in seasons 1967-68 and 1968-69. Also evident in Figure 4.10, is the decline of planting activity since the beginning of the 1970s. Total plantings averaged approximately 1.0 percent of the existing stock from 1975-76 and on. As illustrated in Figures 4.11 and 4.12, a large portion of the total plantings in the last two decades has been replanting activity, while new planting investment has been insignificant over this period. The limited planting activity of white grapefruit over the last decade is rather different from the escalated plantings observed in Florida oranges. This difference could mean that damage from the severe freezes of the 1980s was not as severe for the white grapefruit industry as it was for the orange

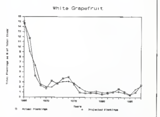

Figure 4.10 Comparisons of Actual and Projected Plantings of White Grapefruit, 1966-67 to 1987-88

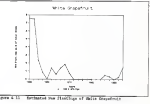

Figure 4 11 Estimated New Plantings of White Grapefruit

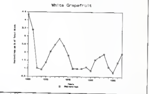

Figure 4 12 Estimated Replantings of White Grapefruit

industry, or that some diversification of freeze-damaged white grapefruit groves to alternative crops has taken place

The stability of the estimated dynamic system was examined by estimating the characteristic roots of the transition matrix ϕ. The roots were calculated as the pair of complex conjugates 0.475 ± 0.2381 whose modulus is 0.530 implying that the system is dynamically stable. Furthermore, the controllability of the estimated system was analyzed by examining the rank of the matrix $[\phi\gamma, \gamma]$. The matrix was found to have full rank indicating that the system is controllable.

A reduced form specification of white grapefruit plantings was estimated with ordinary least squares and the derived parameter estimates are presented in Table 4.8. The results indicate that the explanatory power of the structural specification is greater than that of the reduced form specification.

Colored grapefruit. Planting decisions for Florida colored grapefruit were investigated within the framework of the structural specification (4.1). The estimated structural model was found to explain below fifty percent of the total variation in colored grapefruit plantings which is in contrast with the performance observed in the structural models of planting activities for Florida oranges and white grapefruit.

Extension agents provided two possible explanations for the inadequate modeling of colored grapefruit plantings. First, it was suggested that colored grapefruit variety Ruby Red was introduced in the mid 1960s to Florida growers. Thus, an undetlying diffusion process shaped by the information flow on this new variety could have influenced the observed planting rates of colored grapefruit. Second, it was

suggested that colored grapefruit plantings were to a large extent driven by the industry's optimistic expectations on an expanding European export market of fresh colored grapefruit.

Accounting for such empirical issues could provide a better understanding of the long term investment response of the Florida colored grapefruit industry. However, no efficient way could be identified to incorporate the effect of a possible diffusion process of the new variety on colored grapefruit plantings since the information generating the unknown diffusion path could not be empirically specified. On the other hand, a series of fresh colored grapefruit exports is readily available and the growers could utilize it in order to form expectations about future export demand conditions. Such action would be in agreement with the principle of economically rational expectations.

A series of expected colored grapefruit exports formed as a lagged two year average of actual colored fresh grapefruit exports was employed as an additional explanatory variable in the new plantings equation of the dynamic unobserved components specification. The derived parameter estimates of this specification are presented in Table 4.9. The explanatory power of the model increased through the inclusion of expected exports in the model although a large portion of the total variation still remained unexplained. The estimated coefficient of ϕ_{21} is statistically significant and negative suggesting that past replantings crowded out new planting activity.

Expected exports of fresh grapefruit were found to have a statistically significant positive effect on new plantings denoted by coefficient γ_{22}. Expected real prices of colored grapefruit were found to

Table 4.9. Unobserved Components Model Estimates of Tree Plantings: Colored Grapefruit, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.545	0.388
ϕ_{12}	0.661	0.370
ϕ_{21}	-0.536	0.104
ϕ_{22}	0.463	0.222
γ_{11}	0.179	0.096
γ_{21}	0.394	0.083
γ_{23}	0.405	0.067
γ_{24}	-0.151	0.095

$R^2 = 0.674$
$\rho = 0.071$

Table 4.10. Reduced Form Estimates of Tree Plantings: Colored Grapefruit, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	1.172	5.160
α_1	0.532	0.266
α_2	0.292	0.194
α_3	0.209	0.410
α_4	0.365	0.252
α_5	0.281	0.408

$R^2 = 0.340$
$\rho = 0.138$

have a statistically significant and positive correlation with new plantings captured by the parameter estimate γ_{23}. Opportunity costs represented by total orange expected prices were determined to have a negative influence on new plantings, indicated by parameter estimate γ_{24}, but such influences were not statistically significant. Freeze induced tree losses represented by the estimated index of tree losses w_t lagged by three years, were found to have statistically significant and positive effects on colored grapefruit replantings.

Actual and predicted values of colored grapefruit plantings are illustrated in Figure 4.13. As can be readily seen in the presented graph a large portion of the total variation in colored grapefruit plantings remains unexplained by the estimated model. New plantings and replantings implied by the estimated model are depicted in Figures 4.14 and 4.15, respectively. The projected replanting series exhibits a strong cyclical behavior following tree-killing freezes in periods 1970-71, 1976-77, 1980-81, 1981-82, 1983-84, and 1984-85 suggesting that it takes approximately three seasons for the replacement of tree losses caused by freezes to be completed. The projected new plantings were also compared to the net growth of bearing acreage of colored grapefruit after four years. Such comparisons were possible for plantings performed until 1975-76 which became bearing in 1979-80, before the tree-killing freezes of the 1980s. It was concluded that new plantings and the net growth of the bearing tree stock were closely related.

The dynamic stability of the estimated model was evaluated by measuring the characteristic roots of the transition matrix ϕ. The characteristic roots were estimated as the pair of complex conjugates

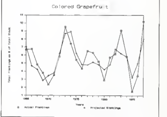

Figure 4.13. Comparisons of Actual and Projected Plantings of Colored Grapefruit, 1966-67 to 1987-88

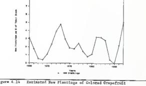

Figure 4.14 Estimated New Plantings of Colored Grapefruit

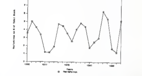

Figure 4.15 Estimated Replantings of Colored Grapefruit

0.504±0.550i whose modulus is 0.776, implying that the estimated system is dynamically stable. The system was also found to be controllable since the matrix $[\phi\gamma,\gamma]$ was determined to be of full rank.

A reduced form model of colored grapefruit plantings was estimated according to specification (4.11) using ordinary least squares and the parameter estimates are reported in Table 4.10. Parameter α_3 represents now the effects of expected exports while α_4 and α_5 denote the effects of expected prices and opportunity costs respectively on colored grapefruit plantings. The results indicate that the estimated reduced form can explain one half of the variation explained by the structural model and one third of the total variation. In addition the statistical significance of the reduced form parameter estimates was limited.

<u>Total grapefruit</u>. Planting activities of Florida total grapefruit were examined within the framework of a dynamic unobserved components structural specification and the estimated coefficients are presented in Table 4.11. The estimated parameters ϕ_{12} and ϕ_{21} were both determined statistically significant, thus empirically supporting the hypothesis that Florida total grapefruit new plantings and replantings are dynamically interdependent.

As with the white and colored grapefruit planting models, expected prices of total grapefruit were found to have a positive and statistically significant influence on new plantings. However, opportunity costs, represented by the expected price of total oranges, were found to be statistically insignificant and to carry a positive sign. Tree losses induced by tree-killing freezes were estimated to have a positive and statistically significant influence on replantings of total grapefruit

Table 4.11 Structural Parameter Estimates of Total Grapefruit Plantings, 1966-67 to 1987-88

Parameter	Estimated Coefficient	Estimated Standard Error
ϕ_{11}	0.424	0.157
ϕ_{12}	0.699	0.091
ϕ_{21}	0.318	0.060
ϕ_{22}	0.610	0.192
γ_{11}	0.204	0.048
γ_{12}	0.134	0.026
γ_{13}	0.015	0.018

$R^2 = 0.839$
$\rho = 0.203$

Table 4.12 Reduced Form Parameter Estimates of Total Grapefruit Plantings, 1966 67 to 1987 88

Parameter	Estimated Coefficient	Estimated Standard Error
α_0	-0.523	2.120
α_1	0.598	0.141
α_2	0.209	0.086
α_3	0.190	0.155
α_4	0.022	0.218

$R^2 = 0.571$
$\rho = -0.045$

The overall adequacy of the estimated model in explaining the variation of total grapefruit plantings is illustrated in Figure 4.16, where actual and predicted plantings are depicted. The estimated model appears to have traced the observed total grapefruit plantings closely with exceptions being the 1966-67 and 1967-68 seasons.

New plantings and replantings of total grapefruit are illustrated in Figures 4.17 and 4.18, respectively. As with colored grapefruit replanting activity has exhibited a cyclical behavior following tree killing freezes. Furthermore, replantings have remained below five percent of the total tree stock in the seasons following the distractive freezes of 1983-84 and 1984-85. These replanting rates are quite lower than those projected for Florida oranges suggesting that the damages to grapefruit tree stock from these freezes were more limited than those absorbed by the orange tree stock.

New plantings and replantings of white and colored grapefruit approximately add up to the projected new plantings and replantings of total grapefruit. However, inconsistencies can also be identified as in the case of new plantings in the 1985-86 season where the projected new plantings for the individual varieties are zero, while the projected new plantings for total grapefruit, although small, are positive.

The dynamic stability of the estimated system of new plantings and replantings of total grapefruit were investigated by estimating the eigenvalues of the transition matrix ϕ. The eigenvalues were estimated as the pair of complex conjugates $0.517 \pm 0.462i$ whose modulus is 0.693 suggesting that the estimated system is dynamically stable. Furthermore,

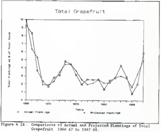

Figure 4 26. Comparisons of Actual and Projected Plantings of Total Grapefruit 1966 67 to 1987 88.

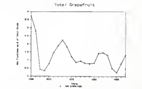

Figure 4 17 Estimated New Plantings of Total Grapefruit

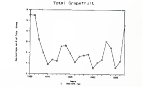

Figure 4 18 Estimated Replantings of Total Grapefruit

the system was found to be controllable as the matrix $[\phi\gamma,\gamma]$ was determined to have full rank equal to two.

A reduced form model of total grapefruit plantings specified according to (4.11) was estimated and the derived parameter estimates are reported in Table 4.12. From the estimated results it may be concluded that the structural model is capable to explain more of the variation in total grapefruit plantings. In addition, the reduced form specification appears to provide misleading information about the correspondence of prices and plantings as no statistically significant price response could be identified within this framework.

The planting series of white and colored have been quit different over the period of the analysis. As it was illustrated earlier, the implied new planting and replanting investments for the two separate grapefruit varieties have also demonstrated different trends. Hence, it should be expected that inferences drawn from the aggregate model may not be relevant to the individual varieties. For example, tree losses were identified to have significant positive effects for total grapefruit replantings while no such effects could be concluded for white grapefruit. On the other hand, opportunity cost were found to have a negative effect on new white grapefruit plantings while no such effects could be shown for total grapefruit.

Summarizing, a number of similarities can be identified in the estimated planting relationships across all Florida citrus varieties, which characterize the long run investment behavior of Florida citrus firms over the period 1966-67 to 1987-88. First, new plantings of Florida citrus were strongly correlated with the relative expected profitability

of each citrus variety. Second, replantings represented approximately 1 to 2 percent of the existing stock in years that there were no tree-killing freezes. Following destructive freezes, increased replanting activity directed towards replacing the damaged trees was observed. Such replacements were completed within three to four seasons after the freeze. Third, the structures of new plantings and replantings of all citrus varieties analyzed in this study were dynamically stable and controllable.

Output Relationships. In this section, interest focuses on the analysis of the short term investment behavior of Florida citrus firms across several citrus varieties and vintages. Structural output relationships for four separate vintages of late and early-midseason oranges as well as white and colored seedless grapefruit were estimated over the period 1969-70 to 1988-89. The estimated output relationships were specified according to equation (4.8) which requires direct computation of the feasible output $Q^f_{t,v}$ levels in any given period t. Feasible per tree output for each citrus variety and vintage were computed according to equation (4.2) by employing the average age-yield profiles reported in Appendix Table B.1 and the aggregate age distributions of mature vintages over the period 1968-69 to 1988-89. The tree stock age distributions of various Florida citrus varieties is reported annually in the Commercial Citrus Inventory published by the Florida Agricultural Statistics. The calculated levels of feasible per tree output by variety and vintage $Q^f_{t,v}$ are reported in Appendix Tables B-2 through B-5.

Actual per tree yields $Q_{t,v}$ for each of the varieties and vintages of interest have been reported annually over the period 1969-70 to 1988-89 and are presented in Appendix Tables B.6 through B.9. Let $Q^a_{t,v}$ denote the

ratio of actual output $Q_{t,v}$ to feasible output $Q^f_{t,v}$ in any given period t. When $Q^e_{t,v}$ is equal to unity, variation in actual output is fully explained by fluctuations in the age distribution of the tree stock. When $Q^e_{t,v}$ is different from unity, $Q_{t,v}$ is different from $Q^f_{t,v}$ and this difference is attributed to weather effects, productivity gains, short run adjustments in the variable input utilization rates, carry over effects of input use in past periods, and random effects.

Early midseason oranges. Output relationships for four vintages of early-midseason oranges over the period 1969-70 to 1988-89 were estimated using ordinary least squares. The parameter estimates along with the R^2 values for each vintage are reported in Table 4.13. Overall, the R^2 of the estimated models are low. This suggests that a large portion of the variation in actual early-midseason orange yields remained unexplained by the estimated output relationships.

Output reductions due to freeze occurrences in the estimated output relationships are captured by the dummy variable W_t. The variable W_t is equal to one for the seasons 1969-70, 1970-71, 1976-77, 1980-81, 1981-82, 1983-84, 1984-85, 1985-86 and equal to zero for all other seasons. Annual weather reports in Citrus Summary which summarize the effects of freeze occurrences on Florida citrus yields, were utilized in order to specify the weather variable W_t. Output reductions due to freezes were not statistically different from zero for early-midseason oranges over the period of interest. These results appear in agreement with a priori expectations about the effects of freezes on Florida early-midseason oranges. Specifically, freezes have, in general, little influence on early-midseason orange production since their harvest is usually completed before the beginning of the freeze sensitive period of the year.

Table 4.13 Estimated Output Relationships for Various Early Midseason Orange Vintages, 1969-70 to 1988-89

4 to 9 Year Old Trees

$$Q^a_t = \underset{(.47)}{0.305} - \underset{(.22)}{0.141}\,W_t + \underset{(.018)}{0.059}\,T_t - \underset{(.27)}{0.004}\,P^a_{t-1} + \underset{(.050)^a}{0.068}\,P_{t-2}$$

$R^2 = 0.50$

10 to 14 Year Old Trees

$$Q^a_t = \underset{(.36)}{0.938} - \underset{(.17)}{0.134}\,W_t + \underset{(.014)}{0.016}\,T_t - \underset{(.21)}{0.054}\,P^a_{t-1} + \underset{(.038)}{0.003}\,P_{t-2}$$

$R^2 = 0.11$

15 to 24 Year Old Trees

$$Q^a_t = \underset{(.17)}{0.930} + \underset{(.08)}{0.004}\,W_t - \underset{(.006)}{0.006}\,T_t + \underset{(.10)}{0.104}\,P^a_{t-1} + \underset{(.018)}{0.002}\,P_{t-2}$$

$R^2 = 0.11$

Over 25 Year Old Trees

$$Q^a_t = \underset{(.17)}{1.092} - \underset{(.08)}{0.099}\,W_t - \underset{(.006)}{0.006}\,T_t + \underset{(.09)}{0.051}\,P^a_{t-1} + \underset{(.018)}{0.0001}\,P_{t-2}$$

$R^2 = 0.17$

[a] Standard Errors in Parentheses

Output increases from new technologies, represented by the coefficient of the linear trend variable T_t, were identified for the first two vintages of early-midseason trees while output reductions were found for the last two vintages. The growth in the yields of trees four to nine years of age was statistically significant and indicated that the output of the trees within this vintage has been increasing at annual rate of 5.5 percent above the feasible output level, over the 1969-70 to 1988-89 period. This output growth appears to be the result of new technologies, such as high density plantings and the use of fertigation systems which increase the productivity of the young trees and decrease the gestation period. Yield increases for trees between ten and fourteen years of age were smaller and not statistically different from zero indicating that output growth from the new technologies has been more important for the first vintage of early-midseason orange trees over the period of analysis. Output reductions of 0.6 percent per year below the feasible output level were found for trees fifteen years of age and older. These output reductions may be attributed to the high density planting technologies which initially increase the physical productivity of young orange trees and subsequently cause yield reductions as the trees become older and the groves become more crowded.

Short run output adjustments in response to deviations of real and expected prices are captured by the variable p^*_{t-1}, which represents the ratio of p_{t-1} and p^*_{t-1}. Statistically significant evidence of such short run adjustments within the framework of early midseason oranges and over the period 1969-70 to 1988-89 could not be identified. The lack of evidence of such output adjustments in the early midseason orange industry

indicates that variable input use is invariant to price changes Some support for such inferences is provided by survey based reports on water and pest management practices of Florida citrus firms (Taylor et al., and Summerhill et al) For example, from 341 citrus firms included in the survey, only a small portion (less than 10 percent) tied irrigation decisions to budgetary considerations

Since the yields of early-midseason oranges in any given period may be influenced by input use in previous periods, lagged real prices could explain some of the variation in normal output. Assuming a maximum carry over effect of two years real prices lagged by two years are used However statistically significant evidence of such dynamic input effects could not be concluded within the framework of early-midseason oranges and over the period 1969-70 to 1988-89

Late oranges Output relationships for four different vintages of late oranges over the period 1969-70 to 1988-89 were estimated and the derived results are presented in Table 4 14 As with early-midseason oranges, the R^2 of the estimated output relationships are rather low indicating that a large portion of the output variation could not be explained by the variables utilized in the regressions

Harvesting of late oranges starts usually in January and hence late oranges are exposed to considerable freeze risk as the freeze sensitive period in Florida begins in December and ends in February In agreement with a priori expectations, freezes were found to have a significant negative effect on the yields of late orange trees ten years of age and older. In particular, in every period that a freeze took place actual output per tree was reduced in average by 37.7 percent below the feasible

Table 4.14 Estimated Output Relationships for Various Late Orange Vintages, 1969-70 to 1986-89

<u>4 to 9 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.38)}{0.616} - \underset{(.17)}{0.040}\, W_t + \underset{(.013)}{0.031}\, T_t \quad \underset{(.23)}{0.243}\, P^{n}_{t-1} + \underset{(.035)^{a}}{0.053}\, P_{t-2}$$

$R^2 = 0.36$

<u>10 to 14 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.45)}{0.873} - \underset{(.19)}{0.377}\, W_t + \underset{(.016)}{0.016}\, T_t \quad \underset{(.27)}{0.074}\, P^{n}_{t-1} + \underset{(.041)}{0.040}\, P_{t-2}$$

$R^2 = 0.28$

<u>15 to 24 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.15)}{1.014} - \underset{(.06)}{0.136}\, W_t - \underset{(.005)}{0.014}\, T_t + \underset{(.09)}{0.052}\, P^{n}_{t-1} + \underset{(.013)}{0.015}\, P_{t-2}$$

$R^2 = 0.45$

<u>Over 25 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.14)}{1.123} - \underset{(.06)}{0.254}\, W_t \quad \underset{(.005)}{0.060}\, T_t + \underset{(.09)}{0.030}\, P^{n}_{t-1} + \underset{(.013)}{0.009}\, P_{t-2}$$

$R^2 = 0.57$

[a] Standard Errors in Parentheses

output level of ten to fourteen year old trees, 13.6 percent below the feasible output of fifteen to twenty-four year old trees, and 25.4 percent below the feasible output of trees over twenty-five years of age.

Output increases from new technologies for late oranges followed the same patterns found in early-midseason oranges. Specifically, statistically significant growth in the yields of trees four to nine years of age was found. This indicates that the output of the trees within this vintage has been increasing at annual rate of 3.1 percent above the feasible output level over the 1969-70 to 1987-88 period. For trees between ten and fourteen years of age yields increased by 1.6 percent per year above the estimated feasible output level. In addition, declining yields at the annual rates of 1.4 and 0.8 percent below the feasible output levels were found for trees in the two last vintages. Hence, high density plantings appear to have similar effects on the physical productivity of late and early midseason orange trees over their productive life cycle.

Statistically significant evidence of short run output adjustments in response to deviations of real and expected prices within the framework of late oranges could not be identified over the period 1969-70 to 1988-89. This lack of responsiveness to price changes through short run output adjustments is in agreement with the findings in the early-midseason orange industry and the survey based information on variable input management practices of Florida citrus firms. Extension specialists suggested that Florida orange growers have traditionally attempted to maximize output from a given tree stock with less attention to production costs since output prices usually remain well above the marginal costs of

production. This position could explain the lack of evidence of short term output adjustments in response to price changes in the orange industry.

As with early-midseason oranges, statistically significant evidence of dynamic input effects could not be identified for late oranges over the period 1969-70 to 1988-89. This finding is consistent with the conclusions drawn about the lack of responsiveness of the orange growers to price changes in terms of short term output adjustments. Specifically, if price changes do not cause significant short term output adjustments, the flows of inputs used in each period remain un-interrupted and hence no correlation should exist between lagged prices and orange output levels.

White grapefruit. Output relationships for four age classes of Florida white grapefruit were estimated over the period 1969-70 to 1988-89, and the parameter estimates are reported in Table 4.15. A number of similarities with the estimated orange output relationships can be readily identified. Overall, the R^2's of the estimated equations are rather low. Hence, a significant portion of the variation in the output of white grapefruit vintages remained unexplained by the estimated relationships. As with early-midseason and late oranges, statistically significant output increases of 3 percent above the feasible output levels were determined for trees between four and nine years old. Output changes for trees between ten and twenty-four years of age were minimal and not statistically different from zero. Furthermore, statistically significant declining yields at an annual average rate of 1.3 below the feasible levels were estimated for white grapefruit trees over twenty-five years of age.

Table 4.15 Estimated Output Relationships for Various White Grapefruit Vintages, 1969-70 to 1966-69

<u>4 to 9 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.38)}{0.191} \quad \underset{(.14)}{0.272}\, W_t + \underset{(.015)}{0.030}\, T_t + \underset{(.19)}{0.315}\, P^{n}_{t-1} + \underset{(.046)^{a}}{0.079}\, P_{t\ 2}$$

$R^2 = 0.55$

<u>10 to 14 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.26)}{1.121} - \underset{(.10)}{0.156}\, W_t - \underset{(.010)}{0.003}\, T_t + \underset{(.13)}{0.217}\, P^{n}_{t\ 1} - \underset{(.024)}{0.025}\, P_{t-2}$$

$R^2 = 0.28$

<u>15 to 24 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.19)}{0.694} - \underset{(.07)}{0.021}\, W_t - \underset{(.007)}{0.005}\, T_t + \underset{(.09)}{0.061}\, P^{n}_{t-1} + \underset{(.017)}{0.006}\, P_{t-2}$$

$R^2 = 0.12$

<u>Over 25 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.13)}{1.333} - \underset{(.05)}{0.174}\, W_t \quad \underset{(.005)}{0.013}\, T_t + \underset{(.06)}{0.131}\, P^{n}_{t-1} - \underset{(.022)}{0.023}\, P_{t-2}$$

$R^2 = 0.57$

a Standard Errors in Parentheses.

Freezes were found to have negative effects on the yields of white grapefruit trees but of varying magnitude for different vintages. The relative output reductions for white grapefruit due to freeze occurrences were more serious for trees between four and nine years of age and over twenty-five years of age.

As with late and early midseason oranges, no dynamic input effects in the production of white grapefruit could be inferred from the estimated output relationships over the period 1969-70 to 1988-89. With regard to short run output adjustments in response to diversions between expected and actual prices, some rather limited evidence supporting the existence of such adjustments for white grapefruit was found. The estimated coefficients of P^{n}_{t-1} were all positive and larger than those in the estimated orange output relationships. However, such short run price responsiveness was statistically significant only for trees over twenty-five years old.

Colored grapefruit. Output relationships for four vintages of Florida colored grapefruit were estimated over the period 1969-70 to 1988-89 and the estimated coefficients are presented in Table 4.16. The values of R^2 for the estimated output relationships were low indicating that a large portion of the variation in colored grapefruit output remained unexplained.

Freeze occurrences were found to have negative effects on the yields of all colored grapefruit vintages but such effects were more serious for trees between four and nine years of age and over twenty-five years of age. These findings are parallel to those obtained for white grapefruit.

Changes in output from the use of new technologies followed the same

Table 4 16 Estimated Output Relationships for Various Colored Grapefruit Vintages 1969-70 to 1988-89

<u>4 to 9 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.39)}{-0.16} - \underset{(.11)}{0.287} W_t + \underset{(.011)}{0.041} T_t + \underset{(.23)}{0.420} P^{n}_{t-1} + \underset{(.027)^{*}}{0.026} P_{t-2}$$

$R^2 = 0.73$

<u>10 to 14 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.37)}{0.756} - \underset{(.11)}{0.134} W_t + \underset{(.010)}{0.009} T_t + \underset{(.22)}{0.269} P^{n}_{t-1} \quad \underset{(.026)}{0.014} P_{t-2}$$

$R^2 = 0.26$

<u>15 to 24 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.25)}{0.878} - \underset{(.07)}{0.006} W_t \quad \underset{(.007)}{0.007} T_t + \underset{(.14)}{0.062} P^{n}_{t-1} + \underset{(.018)}{0.009} P_{t-2}$$

$R^2 = 0.15$

<u>Over 25 Year Old Trees</u>

$$Q^{n}_{t} = \underset{(.15)}{0.646} - \underset{(.04)}{0.118} W_t \quad \underset{(.004)}{0.003} T_t + \underset{(.09)}{0.254} P^{n}_{t-1} + \underset{(.011)}{0.011} P_{t-2}$$

$R^2 = 0.54$

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* Standard Errors in Parentheses

patterns observed in the estimated output relationships for all other citrus varieties. Specifically, the output of four to nine year old trees was found to have grown at an average annual rate of 4.1 percent above the estimated feasible levels over the period 1969-70 to 1988-89. However, a smaller output growth, not statistically different from zero, could be inferred for trees between ten and fourteen years of age. In addition, a slight reduction in the output of trees in the last two age classes below the estimated feasible output levels were concluded.

As with white grapefruit, some rather narrow evidence of short run output adjustments in response to deviations in the actual and expected prices were provided by the estimated output relationships for colored grapefruit. The estimated coefficients of p^{a}_{t-1} were all positive but statistically different from zero only for trees in the age classes of four to nine years old and over twenty-five years old. Finally, no statistically significant dynamic input effects could be identified for Florida colored grapefruit over the period 1969-70 to 1988-89.

CHAPTER V
SUMMARY AND CONCLUSIONS

Economic Implications

Historically, the Florida citrus industry has been an important participant in both the U.S. and international citrus markets. During the decade of 1980s, however, its productive capacity was substantially reduced by the unprecedented occurrence of several tree killing freezes. These events increased the need for information on the economic structure of investment and output supply of Florida citrus. In response to these informational needs, this study investigated the structures of investment and supply response of various Florida citrus varieties.

In general, the output of the Florida citrus industry can be varied through planting decisions in the long run and through cultivation decisions in the short run. These decisions possess differential dynamic structures and hence represent alternative adjustment mechanisms for the Florida citrus industry. Because of the qualitative differences among investment decisions, economic analysis of Florida citrus investment and supply response requires the separate investigation of planting and cultivation decisions. A complete structural system of planting and cultivation decisions was specified for different Florida citrus varieties. In the absence of the necessary data for direct structural estimation of Florida citrus tree planting decisions, new plantings and replantings were considered latent variables and a structural system was

estimated within the framework of a dynamic unobserved components model Structural output relationships, capturing short term cultivation decisions, were directly estimable

From the empirical estimation of the Florida citrus planting relationships, inferences could be made with respect to the proposed methodological approach and with regard to the economic implications of the empirical results for the Florida citrus industry In terms of the methodology employed for structural estimation of planting activities the empirical models of Florida citrus planting relationships cast within the framework of the dynamic unobserved components model performed satisfactorily The estimated models accounted for a large portion of the variation in Florida citrus plantings and provided parameter estimates which were, in most cases, statistically significant and had signs consistent with a priori expectations Furthermore, the implied levels of the unobserved new plantings and replantings appeared consistent with observed regularities in the Florida citrus industry

Statistically, the estimated structural models of Florida citrus planting activities compared favorably to single equation reduced form planting models across all the citrus varieties investigated in this study The estimated structural relationships explained a larger portion of the variation in Florida citrus plantings and yielded parameter estimates of greater statistical significance than those derived from the reduced form models Indeed, due to the lack of statistical significance of some reduced form coefficients, the implied economic structures of Florida citrus acreage response were substantially different from those implied by the structural models For example, while strong correlation

between expected citrus prices and Florida citrus acreage response were identified through the structural planting models, no such correlations could be inferred from the reduced form models.

Meaningful insights about the economic structure of long term investment behavior of Florida citrus were obtained by separately investigating new plantings and replantings. New plantings, which constitute net growth to the stock of Florida citrus trees, were directly related to economic expectations of citrus firms and were distinguished from replantings which were tied to the size of the tree stock and to non-periodic freeze occurrences. Such information provides a better understanding of the economic structure of Florida citrus investment and is not attainable from reduced form specifications.

A test of the hypothesis of dynamic interdependence between new planting and replanting was also possible within the framework of the structural models of Florida citrus plantings. The interdependence coefficients ϕ_{12} and ϕ_{21} were found in many of the estimated models to be statistically different from zero. Hence, some empirical evidence supporting the hypothesis of dynamic interdependence between new plantings and replantings was provided. In the absence of analytical solutions to the optimization problem of the Florida citrus firm, no sign conventions for the coefficients of ϕ_{12} and ϕ_{21} exist. The parameter ϕ_{12}, which captures the effects of previous period new plantings on current period replantings, appeared with both positive and negative signs in the estimated planting models providing mixed signals on the possible effects of new plantings on replantings. The parameter ϕ_{21}, which denotes the influence of previous period replantings on current period new plantings,

however carried a negative signs in all estimated models indicating that toplantings crowded out new plantings of Florida citrus. This effect appears reasonable as increased replanting activity increases the expected future productive capacity of the citrus industry and could discourage new tree plantings. In summary the methodology employed provided economically consistent and empirically relevant results that were judged superior to those obtained from the alternative reduced form specification.

Overall, the investment behavior of Florida citrus firms appeared to be homogeneous across all citrus varieties examined in this study over the period 1966-67 to 1987-88. A common characteristic across all estimated planting relationships was the responsiveness of the planting decisions to economic stimuli. In particular, citrus growers were found to form expectations on the relative profitability of Florida citrus and to employ these expectations to guide long term investment decisions. As a result, new plantings of Florida citrus were minimal in periods of low prices. Replantings on the other hand were found to be performed regularly, replacing trees damaged by diseases and freezes even in periods of low prices. Following tree-killing freezes replanting activity directed towards replacing the damaged trees was found to be completed in three to four years.

The empirical results derived from the estimation of colored grapefruit planting activities indicate that firms may employ multiple economic indicators in forming expectations. The increasing size of European export market implied increased demand conditions for fresh colored grapefruit and activated additional new plantings. Similar

investment behavior should be expected for all Florida citrus varieties signifying that when market signals in the form of prices or any other information on future market conditions are available, firms are likely to process and respond to the signals in as economically consistent manner. Such conclusions have clear implications about future plantings of white grapefruit after the recent expansions of the Japanese fresh white grapefruit market.

One issue of great importance for the Florida citrus industry is that of stability. Given the significant gestation and production lags of citrus production, tree stock levels that appear "optimal" in some given period may be sub-optimal T periods later when expectations are not fully realized. Over-investment due to erroneous expectations could cause long periods of low prices and financial stress which in turn could result in under investment. In the case that over-investment and under-investment are not dampened over time, instabilities could result. Some evidence of stability for the Florida citrus industry was provided by the estimated planting relationships as all planting systems were found to be dynamically stable and controllable.

In addition to analyzing the economic structure of planting activities, structural output relationships were estimated. Detailed data on actual yields by variety and vintage, the tree stock age distributions, and age-yield profiles by variety allowed direct estimation of structural output relationships for various citrus varieties by vintage. Such detailed estimation of output relationships had not been previously achieved in perennial supply response studies. However, the overall statistical performance of the estimated output relationships was less

than satisfactory as a large portion of the variation remained unexplained. Despite the lack of statistical precision, a number of useful inferences could be made from the estimated output relationships.

Foremost, it should be pointed out that since R^2 is defined as the reduction in the variation about the mean, if the mean is the best predictor of the dependent variable the estimated relationship may be reasonable even with low R^2. A number of physical factors, such as air temperatures, winds, and rainfall can significantly affect the processes of blooming, fruit setting and eventually the yields of Florida citrus from one year to another. Such "normal" yield variation is not captured by the estimated output relationships. The extent to which Florida citrus firms maintain fixed input management practices, the yields of Florida citrus may vary in response to random factors only. In such a case, output relationships with low R^2 would imply that the best predictors of per tree yields are the levels of feasible output.

Probably the most important implication of the estimated Florida citrus output relationships relates to the general lack of evidence concerning short term output adjustments through variations in the input utilization rates in response to economic stimuli. From a total of sixteen output relationships for four citrus varieties and vintages, only three exhibited statistically significant evidence of such short run output adjustments. This finding is in agreement with assessments by extension specialists and recent survey results on input utilization and cultivation practices in the Florida citrus industry. Hence, it may be concluded that output adjustments in response to economic changes in the Florida citrus industry occur mainly through long term adjustments in the

productive capacity of the tree stock

From the estimated output relationships it may be also inferred that the use of such new technologies as high density plantings have induced a re-distribution of output over the productive life cycle of Florida citrus trees by increasing the yields of four to fourteen year old trees and reducing the yields of trees over fifteen years of age. The largest gains in yields have been experienced by young citrus trees four to nine years of age while output changes for trees over ten years of age have been rather small.

It is well known among Florida citrus producers that high density plantings along with improved irrigation systems reduce the gestation period and increase the per tree output of young citrus trees. However, the effects of such technologies on older citrus trees are less known, although it is often suggested that the crowding effect in the citrus grove would most probably result into a relative reduction in the per tree output. The empirical results of the estimated output relationships suggest that, so far, the relative reductions in the yields of older citrus trees have been small. From the perspective of a citrus grower, such yield decreases when discounted to the date of initial investment become even more unimportant. Finally, it should be noted that on a per acre basis output increases are far more important. Recent citrus planting systems in Florida utilize one hundred and forty trees per acre as opposed to the traditional seventy trees per acre planting practices. The greater number of trees in combination with the yield redistributions found in the estimated output relationships imply that substantial increases in the aggregate Florida citrus output should be expected.

Suggestions for Further Research

Structural analysis of perennial supply response has been typically limited by a paucity of data. The empirical results of this study provided encouraging evidence that structural estimation of perennial supply response may be possible even in the absence of detailed data within the framework of a dynamic unobserved components model. Further empirical analysis, however, is required to fully assess the value and applicability of this structural approach. Extensions of the estimated model should be possible for various perennial crops with different agronomic characteristics. Potential applications of interest would involve perennials with more complex planting decision sets than those that typify Florida citrus.

One often encountered perennial planting decision set includes new plantings, replantings, and uprootings of uneconomic vintages. The specification of such decision set within the framework of a dynamic unobserved components structural model should be adapted to the data which may be available to the analyst. In particular, in the case that only bearing acreage data is available, the model would involve three transition equations, one for each planting activity, and one measurement equation where the measurable bearing acreage in period t equals new plantings in period t-g plus replantings in period t-g minus uprootings in period t-1. In the case that uprootings are directly measurable, as in French et al., an additional measurement equation can be specified to assist the estimation.

APPENDIX A

DATA REQUIRED FOR THE ESTIMATION OF PLANTING RELATIONSHIPS

The data required for the estimation of the Florida citrus planting decisions examined in chapter four are presented and discussed in this section. Nominal on tree prices are reported annually in Citrus Summary and are reproduced in Tables A.1 and A.2 for all Florida citrus varieties of interest. Florida citrus production costs are reported in Table A.3. The normalized prices used in the estimation of the Florida citrus planting relationships were constructed by multiplying the ratio of nominal on tree prices to total planting costs by 1000 (i.e. $1000*(P_t/C_t)$).

Planted acres of Florida citrus are presented in Tables A.4 and A.5. Small inconsistencies were observed in the reported plantings from one tree inventory to another. In some cases the reported plantings for a given year were revised upward in later inventories. In such cases the largest number reported was recorded.

Some difficulties were encountered in the specification of the planted acreage series of early-midseason and late oranges as well as white and colored grapefruit. In each tree inventory the initial designation of newly planted Florida citrus by variety includes a large portion of unidentified planted acres. It takes approximately four years to fully identify all planted acres by variety. However, in some cases, when planted acres were fully identified some of the original planted acreages were lost due largely to freezes but also due to diseases and

pest infestations. The plantings of early-midseason and late oranges as well as white and colored grapefruit reported in Tables A 4 and A 5 were obtained by multiplying the initially reported total orange and grapefruit plantings by each variety's share as estimated after all planted acres were fully identified.

Estimated losses of Florida citrus bearing acreage due to tree killing freezes were used to construct an approximate index of destructiveness for the tree killing freezes which occurred between 1966-67 and 1967-68. The estimation of total grapefruit and total orange bearing acreage losses are presented in Tables A 6 and A 9, respectively. In the estimation of such losses several assumptions were made. First, an average natural attrition rate of two percent per year was assumed for all Florida citrus bearing acreage. Second, in the absence of tree-killing freezes, all newly planted citrus trees were assumed to become bearing four years later. Under normal weather conditions, the expected bearing acreage in a given year equals actual bearing acreage in the previous year less attrition plus planted acreage four years previous. The expected acreages for total oranges and total grapefruit were estimated in this manner over the period 1966-67 to 1987-88. For example, the expected bearing acreage of total oranges for the 1966-67 season was estimated to be 509.0 thousand acres which is equal to 46.4 thousand planted acres in 1962-63 and 96 percent of the 672.0 thousand bearing acres in the 1965-66 season. The difference between actual and expected bearing acreage is expected to approximate the losses resulting from tree-killing freezes.

It should be noted that in most cases differences between expected and actual acreage appeared in the seasons subsequent to a tree-killing

freezes. Tree-killing freezes usually occur between December and February. Aerial photographs of Florida citrus acreage are taken during the months of December and January while locational surveys of the photographed areas are performed between February and May. Given that it often takes several months after a freeze for one to verify the extent of the freeze damage on Florida citrus trees, it is not until the year following a tree-killing freeze that freeze induced tree losses are fully accounted for. Because of this particularity, difficulties were encountered in the estimation of tree losses in cases of sequential freezes. In such cases, the allocation of the estimated differences between expected and actual bearing acreage to various freezes were based on the relative destructiveness of each freeze as documented in the annual weather report of the Citrus Summary and similar information provided by the staff of the Florida Agricultural Statistical Service.

Based on these considerations the weather index w_t utilized in the planting relationships of Florida grapefruit was estimated as following. For the years that no tree-killing freezes were observed any differences between expected and actual bearing acreage were considered equal to zero. The index was then estimated to be 2.0 for the season 1970-71, 2.7 for the season 1976-77, 1.0 for the season 1980-81, and 10.0 for the season 1983-84. For the season 1984-85, the index was set equal to 12.3 which is equal to 3.6, the estimated difference in 1984-85, and 3/4 of the estimated difference in 1985-86. Finally, the index was equal to 2.9 for the season 1985-86, which is equal to 1/4 of the estimated 11.6 difference between expected and actual bearing acreage in 1985-86.

The weather index w_t employed in the orange planting relationships

was estimated in the following way The freeze induced losses due to the 1970-71 freeze were set equal to 46 3 while the tree losses from the 1976-77 freeze were set equal to 8 4 Tree losses generated by the 1980-81 freeze were set equal to 29 6 which is equal to 12 3 the estimated difference in 1980-81, plus 3/4 of the estimated difference in 1981-82 Tree losses from the rather minor freeze in the 1981-82 season were set equal to 5 75 which is equal to 1/4 of the estimated difference in 1981-82 Tree losses due to the freeze in 1983-84 were set equal to 86 7 which equals 70 8 the estimated difference in 1983 84, plus 1/4 of the estimated difference in 1984 85 Tree losses due to the 1984-85 freeze were set equal to 95 9 which equals 3/4 of the estimated difference in 1984 85 and 2/3 of the estimated difference in 1985 86 Finally, the estimated losses due to the 1985-86 freeze were set equal to 24 1 which equals 1/3 of the estimated losses in 1985-86 For the years that no tree-killing freezes were observed, freeze induced tree losses were assumed zero The weather index w_t was then derived by dividing the above figures by 5 75 the estimated losses in 1981 82

Table A 1 Nominal On Tree Prices of Florida Oranges, 1962-63 to 1987-88

Season	Early-Midseason	Late	Total
	-$/box-	-$/box-	-$/box-
1962-63	2.17	3.50	2.71
1963-64	4.43	4.45	4.44
1964-65	2.57	2.28	2.43
1965-66	1.44	1.79	1.62
1966-67	0.81	1.08	0.96
1967-68	1.86	2.28	2.07
1968-69	1.56	1.85	1.68
1969-70	1.15	1.13	1.14
1970-71	1.10	1.91	1.46
1971-72	1.98	2.11	2.04
1972-73	1.43	1.71	1.56
1973-74	1.38	1.59	1.47
1974-75	1.46	1.82	1.62
1975-76	1.69	1.88	1.77
1976-77	1.89	2.63	2.17
1977-78	3.90	4.40	4.14
1978-79	4.44	6.95	4.66
1979-80	3.59	3.89	3.72
1980-81	3.67	4.63	4.04
1981-82	4.27	4.29	4.28
1982-83	4.88	5.41	5.15
1983-84	5.09	6.72	5.75
1984-85	7.30	6.88	7.10
1985-86	3.92	5.97	3.94
1986-87	4.56	6.02	5.22
1987-88	6.72	8.73	7.38

Source Citrus Summary, various issues

Table A.2 Nominal On Tree Prices of Florida Grapefruit, 1962-63 to 1987-88

Season	White	Colored	Total
	$/box	-$/box-	-$/box-
1962-63	1.29	1.81	1.24
1963-64	2.24	2.54	2.24
1964-65	1.51	1.82	1.47
1965-66	1.39	1.64	1.36
1966-67	0.73	0.94	0.74
1967-68	2.05	2.48	2.01
1968-69	0.98	1.15	0.98
1969-70	1.72	1.92	1.70
1970-71	1.89	2.15	1.91
1971-72	2.27	2.69	2.32
1972-73	2.06	2.53	2.08
1973-74	1.58	2.12	1.66
1974-75	1.55	2.59	1.72
1975-76	1.29	2.23	1.47
1976-77	1.49	2.04	1.58
1977-78	1.47	2.09	1.67
1978-79	2.21	3.13	2.41
1979-80	3.12	3.80	3.31
1980-81	3.46	4.22	3.60
1981-82	1.92	2.80	2.09
1982-83	1.51	3.20	1.96
1983-84	2.08	4.05	2.72
1984-85	3.02	4.84	3.67
1985-86	3.56	4.98	4.09
1986-87	4.45	5.80	4.96
1987-88	5.35	5.93	5.57

Source: Citrus Summary, various issues

Table A 3 Florida Citrus Production and Replanting Costs, 1962-63 to 1987-88

Season	Production Costs	Replanting Costs
	-$/acre-	-$/acre
1962-63	233.79	31.46
1963-64	236.10	31.77
1964-65	239.91	32.01
1965-66	241.76	32.53
1966-67	199.33	26.82
1967-68	184.00	24.76
1968-69	185.73	25.03
1969-70	188.64	25.40
1970-71	193.35	26.07
1971-72	207.98	28.02
1972-73	229.55	31.52
1973-74	284.74	37.02
1974-75	330.50	40.98
1975-76	323.33	42.21
1976-77	336.19	42.35
1977-78	345.96	44.64
1978-79	381.36	48.47
1979-80	442.69	54.36
1980-81	519.41	60.84
1981-82	551.62	61.46
1982-83	566.15	61.69
1983-84	582.17	54.18
1984-85	623.27	59.89
1985-86	613.34	51.57
1986-87	630.38	53.77
1987-88	704.52	69.80

Sources Murero, R Florida Citrus Production Costs undated
Florida Citrus Mutual, Annual Statistical Report various issues

Table A-4 Planted Acres of Florida Oranges, 1965-66 to 1987-88.

Season	Early-Midseason	Late	Total
	-acres-	-acres-	-acres-
1965-66	39057	25214	64271
1966-67	21483	12359	33842
1967-68	11482	11714	23196
1968-69	5639	5823	11462
1969-70	6561	7459	14020
1970-71	5526	3420	8946
1971-72	2288	2044	4332
1972-73	5147	5443	10590
1973-74	2968	2109	5077
1974-75	4685	3263	7948
1975-76	5064	4589	9653
1976-77	5150	4775	9926
1977-78	5411	5238	10649
1978-79	5788	5141	10929
1979-80	9931	9083	19014
1980-81	9527	9256	18783
1981-82	17908	10352	28261
1982-83	14599	8127	22726
1983-84	25039	13854	38893
1984-85	13058	7529	20587
1985-86	12949	9339	22289
1986-87	24722	17865	42587
1987-88	37810	32142	69952

Source: *Commercial Citrus Inventory*, various issues

Table A 5 Planted Acres of Florida Grapefruit, 1965-66 to 1987-88

Season	White	Colored	Total
	-acres-	acres-	acres
1965-66	7749	1824	10095
1966-67	7238	1830	9579
1967-68	6594	1967	9420
1968-69	2660	1485	4406
1969-70	1497	1215	2915
1970-71	1126	766	2095
1971-72	2148	1182	3537
1972-73	2795	1973	3926
1973-74	2490	3345	6152
1974-75	2765	2845	5891
1975-76	1782	2192	4257
1976-77	697	1843	2753
1977-78	600	2829	3621
1978-79	604	2820	3521
1979-80	609	2454	3654
1980-81	439	1438	1947
1981-82	584	2809	3457
1982-83	684	3218	3957
1983-84	1134	4926	6184
1984-85	713	3265	3986
1985-86	312	887	1151
1986-87	550	1852	2445
1987-88	1390	5551	7049

Source: Commercial Citrus Inventory, various issues

Table A 6 Total Tree Stock of Florida Oranges, 1964-65 to 1987-88

Season	Early-Midseason	Late	Total
	-acres-	-acres-	-acres-
1964-65	317079	296533	615497
1965-66	357011	321861	695824
1966-67	377531	334485	698516
1967-68	383636	342172	713400
1968-69	373318	343910	714544
1969-70	377465	341155	715806
1970-71	377508	340616	710866
1971-72	343208	319746	659418
1972-73	339816	317666	654141
1973-74	332223	311316	642431
1974-75	329882	308459	637677
1975-76	326258	303404	628567
1976-77	324761	302136	626029
1977-78	319304	297865	616020
1978-79	316907	295743	612698
1979-80	325174	301937	627174
1980-81	327857	304918	632088
1981-82	332754	304432	636864
1982-83	329765	295818	611173
1983-84	304373	278589	573991
1984-85	268904	261662	515925
1985-86	247945	224149	466252
1986-87	264868	234887	493564
1987-88	286639	248975	536737

Source: Commercial Citrus Inventory, various issues

Table A.7 Total Tree stock of Florida Grapefruit, 1964-65 to 1987-88

Season	White	Colored	Total
	-acres-	-acres-	-acres-
1964-65	41076	25383	93205
1965-66	69125	27327	103344
1966-67	56244	29083	113713
1967-68	62317	30687	120427
1968-69	64541	32006	123879
1969-70	65189	32897	125020
1970-71	65844	33633	126008
1971-72	66431	33768	125437
1972-73	66866	35136	127111
1973-74	68859	38166	131391
1974-75	10298	40345	135144
1975-76	72132	42355	138222
1976-77	71336	43425	138517
1977-78	10044	44809	136990
1978-79	69683	46984	138715
1979-80	69410	49446	139926
1980-81	68851	48986	138325
1981-82	68036	52266	140387
1982-83	67716	54164	141787
1983-86	63341	56236	035157
1984-85	61315	58818	133076
1985-86	56263	53696	120450
1986-87	55709	54430	120008
1987-88	54565	57055	120631

Source: Commercial Citrus Inventory, various issues

Table A.8 Estimated Losses of Grapefruit Bearing Acreage Due to Tree-Killing Freezes, 1966-67 to 1987-88

Actual Plantings (period T-4)	Bearing Acreage (period T-1)	Expected Acreage (period T)	Actual Acreage (period T)	Difference (period T)
-------------	----------	thousand acres	----------	----------
1.3	85.8	85.4	87.0	1.6
2.3	87.0	87.6	87.5	0.1
3.6	87.5	89.3	90.3	-1.0
10.0	90.3	98.5	98.7	-0.2
9.6	98.7	106.3	107.2	-0.9
9.4	107.2	114.5	112.6	2.0
4.4	112.6	114.7	114.6	0.1
2.9	114.6	115.2	115.8	-0.6
2.1	115.8	115.6	115.4	0.2
3.5	115.4	116.6	117.9	0.7
3.9	117.9	119.4	119.3	0.1
6.2	119.3	123.0	120.3	2.7
5.9	120.3	123.8	124.6	-0.8
4.3	124.6	126.4	126.4	0.0
2.8	126.4	126.6	125.6	1.0
3.6	125.6	126.8	127.8	-1.0
3.5	127.8	128.7	128.6	0.1
3.6	128.6	129.6	119.6	10.0
1.9	119.6	119.1	115.5	3.6
3.5	115.5	116.7	105.1	11.6
3.9	105.1	106.9	106.0	0.9
6.2	106.8	110.0	106.8	3.2

Table A 9 Estimated Losses of Orange Bearing Acreage Due to Tree-Killing Freezes 1966-67 to 1987-88.

Actual Plantings (period T-4)	Bearing Acreage (period T 1)	Expected Acreage (period T)	Actual Acreage (period T)	Difference (period T)
------------------------	------ thousand	acres ------	------------------------	
46.4	472.0	509.0	522.0	-13.8
40.9	322.0	552.3	337.6	-5.1
42.6	337.6	589.0	393.6	-6.6
64.3	395.6	647.9	636.1	11.8
33.8	636.1	637.2	660.5	-3.3
23.2	660.3	670.3	624.2	46.3
11.5	624.2	623.2	619.6	3.6
14.0	619.6	621.2	614.6	6.6
8.9	614.6	611.2	610.4	0.8
4.4	610.4	602.6	596.4	6.2
10.6	596.4	563.1	594.3	0.8
5.0	594.3	387.6	579.0	8.4
7.9	579.0	373.3	571.5	3.8
9.6	571.5	569.7	576.6	6.9
9.9	576.6	575.0	573.4	1.6
10.6	373.4	572.5	560.2	12.3
10.9	360.2	559.9	336.8	23.1
19.0	336.8	545.1	474.3	70.8
18.8	474.3	483.6	420.1	63.5
28.3	420.1	440.0	367.6	72.4
22.7	367.6	382.9	375.4	7.5
38.9	375.4	406.8	382.9	23.9

Table A.10 Florida Exports of Fresh Colored Grapefruit, 1964-65 to 1988-89

Season	Quantity Exported
	-4/5 bu boxes-
1964-65	130814
1965-66	163276
1966-67	219844
1967-68	222004
1968-69	318018
1969-70	306882
1970-71	298742
1971-72	492422
1972-73	907065
1973-74	1060496
1974-75	1422975
1975-76	2344240
1976-77	1825415
1977-78	2607299
1978-79	4001375
1979-80	4485279
1980-81	4267286
1981-82	3467762
1982-83	3296940
1983-84	3874525
1984-85	3268546
1985-86	5297967
1986-87	7399941
1987-88	9911930
1988-89	12296665

Source: Department of Agriculture, Division of Fruit and Vegetable Inspection

APPENDIX B

DATA REQUIRED FOR THE ESTIMATION OF OUTPUT RELATIONSHIPS

Table B-1 Age-Yield Profiles for Various Florida Citrus Crops

Age of Tree	Early-Midseason Oranges	Late Oranges	Seedless Grapefruit
	-boxes/tree-	-boxes/tree-	-boxes/tree-
4	0.68	0.66	1.44
5	0.85	0.85	1.80
6	1.02	1.02	2.16
7	1.28	1.18	2.55
8	1.59	1.34	2.97
9	1.92	1.50	3.39
10	2.25	1.66	3.81
11	2.58	1.82	4.23
12	2.80	2.00	4.64
13	3.07	2.17	4.90
14	3.26	2.36	5.14
15	3.45	2.55	5.38
16	3.64	2.74	5.62
17	3.83	2.93	5.86
18	4.02	3.12	6.10
19	4.21	3.31	6.34
20	4.37	3.47	6.55
21	4.52	3.42	6.73
22	4.67	3.77	6.81
23	4.82	3.92	7.09
24	4.97	4.07	7.27
25 & over	5.10	4.20	7.44

Source Florida Citrus Mutual, Annual Statistical Report, 1978

Table B.2. Estimated Feasible Per Tree Yields of Early-Midseason Oranges for Various Age Classes, 1969-70 to 1988-89

Season	Age Class 4-9	10-14	15-24
	-boxes-	-boxes-	-boxes-
1969-70	1.13	2.71	4.05
1970-71	1.17	2.70	3.99
1971-72	1.17	2.60	4.00
1972-73	1.25	2.66	4.00
1973-74	1.34	2.72	4.04
1974-75	1.43	2.74	3.84
1975-76	1.49	2.79	3.95
1976-77	1.46	2.74	3.86
1977-78	1.33	2.81	3.87
1978-79	1.28	2.88	3.86
1979-80	1.28	2.97	3.89
1980-81	1.23	3.00	3.96
1981-82	1.16	2.95	3.95
1982-83	1.20	2.94	4.00
1983-84	1.15	2.81	4.08
1984-85	1.15	2.85	4.15
1985-86	1.11	2.80	4.22
1986-87	1.04	2.76	4.27
1987-88	1.03	2.81	4.33
1988-89	1.01	2.76	4.31

Table B 3 Estimated Feasible Per Tree Yields of Late Oranges for Various Age Classes, 1969-70 to 1988-89

Season	Age Class 4-9	10-14	15-24
	-boxes-	-boxes-	-boxes-
1969-70	1.05	2.02	3.18
1970-71	1.07	1.98	3.08
1971-72	1.09	1.91	3.11
1972-73	1.11	1.97	3.14
1973-74	1.18	1.94	3.19
1974-75	1.20	1.95	3.14
1975-76	1.23	1.99	3.17
1976-77	1.23	1.97	3.11
1977-78	1.17	2.01	3.10
1978-79	1.13	2.02	3.02
1979-80	1.14	2.08	3.04
1980-81	1.09	2.10	3.08
1981-82	1.07	2.09	3.08
1982-83	1.10	2.10	3.06
1983-84	1.05	1.98	3.2
1984-85	1.04	2.03	3.28
1985-86	1.02	2.00	3.30
1986-87	1.01	1.98	3.34
1987-88	1.02	2.02	3.40
1988-89	1.00	1.95	3.33

Table # 4 Estimated Feasible Per Tree Yields of White Grapefruit for Various Age Classes, 1969-70 to 1988-89.

Season	4-9	10-14	15-24
	Age Class		
	-boxes-	-boxes-	-boxes-
1969-70	2.13	4.23	6.30
1970-71	1.92	4.22	6.26
1971-72	1.91	4.22	6.28
1972-73	2.01	4.33	3.29
1973-74	2.26	4.32	6.34
1974-75	2.53	4.46	5.97
1975-76	2.78	4.36	5.88
1976-77	2.79	4.16	5.80
1977-78	2.71	4.22	5.83
1978-79	2.37	4.38	5.91
1979-80	2.20	4.59	5.92
1980-81	2.28	4.77	5.89
1981-82	2.49	4.84	5.76
1982-83	2.63	4.77	5.76
1983-84	2.80	4.59	5.83
1984-85	2.82	4.44	5.97
1985-86	2.69	4.41	6.13
1986-87	2.40	4.54	6.30
1987-88	2.32	4.67	6.42
1988-89	2.24	4.81	6.51

Table 8 5 Estimated Feasible Per Tree Yields of Colored Grapefruit for Various Age Classes, 1969 70 to 1988-89

Season	4-9	10-14	15-24
	Age Class		
	-boxes-	-boxes	-boxes-
1969-70	2 20	4 71	6 23
1970-71	1 8	4 68	6 32
1971-72	1 75	4 44	6 37
1972-73	1 89	4 65	6 46
1973-74	2 08	4 69	6 56
1974-75	2 30	4 51	8 49
1975-76	2 54	4 35	6 52
1976-77	2 54	5 01	6 49
1977-78	2 45	4 14	6 44
1978-79	2 15	4 61	6 05
1979-80	2 08	4 46	6 15
1980-81	2 15	4 61	6 05
1981-82	2 52	4 68	5 72
1982-83	2 59	4 65	5 86
1983-84	2 46	4 50	5 73
1984-85	2 42	4 31	5 85
1985-86	2 59	4 65	5 66
1986-87	2 55	4 47	6 11
1987-88	2 35	4 61	6 21
1988-89	2 30	4 61	6 25

Table B.6 Actual Per Tree Yields of Early-Midseason Oranges for Various Age Classes, 1969-70 to 1988-89

	Age Class			
Season	4-9	10-14	15-24	25 & over
	-boxes-	-boxes-	-boxes-	-boxes-
1969-70	1.3	2.5	4.2	5.0
1970-71	1.5	2.8	4.1	5.4
1971-72	1.1	1.8	3.0	5.2
1972-73	1.7	2.8	4.6	6.1
1973-74	1.7	3.2	4.2	5.3
1974-75	1.6	2.9	4.2	6.2
1975-76	1.3	3.1	4.4	5.5
1976-77	1.6	3.5	4.9	6.5
1977-78	1.1	2.3	3.7	5.3
1978-79	1.2	2.5	3.8	5.0
1979-80	2.1	3.0	4.6	6.6
1980-81	1.7	2.9	4.1	5.8
1981-82	1.2	1.7	3.0	4.0
1982-83	0.9	0.8	2.7	4.7
1983-84	1.3	2.0	3.2	3.7
1984-85	2.2	2.3	3.6	3.9
1985-86	2.2	3.3	4.9	5.8
1986-87	2.3	3.6	4.2	4.9
1987-88	2.3	4.6	4.3	5.8
1988-89	3.0	4.8	4.4	5.8

Source: Florida Citrus Mutual, Annual Statistical Report, various issues.

Table B 7 Actual Per Tree Yields of Late Oranges for Various Age Classes, 1967-70 to 1988-89

Season	Age Class			
	4 9	10-14	13-24	25 & over
	-boxes-	-boxes-	boxes-	-boxes-
1969-70	1 0	2 2	3 4	4 6
1970-71	1 3	2 0	3 3	3 9
1971-72	1 1	1 8	3 1	3 1
1972-73	1 3	2 8	4 1	3 3
1973-74	1.3	2 8	3 3	4 3
1974-73	1 3	2 3	3 3	4 8
1975-76	0 9	2 6	3 7	3 0
1976-77	1 3	2 0	3 2	4 3
1977-78	1 0	2 3	3 4	4 9
1978-79	0 6	2 2	3 0	4 4
1979-80	1 4	2 4	3 7	5 1
1980-81	1 3	2 0	2 8	3 7
1981 82	0 7	1 2	2 0	3 2
1982-83	0 7	0 8	2 6	4 8
1983-84	1 1	1 4	2 3	2 3
1984 83	1 8	1 3	2 8	3 3
1985-86	1 5	3 6	3 7	4 8
1986-87	2 1	3 4	3 1	4 1
1987-88	1 3	3.3	3 3	4 8
1988-89	1 6	3 8	3 9	3 0

Source Florida Citrus Mutual, Annual Statistical Report, various issues

Table 3.8 Actual Per Tree Yields of White Grapefruit for Various Age Classes, 1969-70 to 1988-89

Season	Age Class			
	4-9	10-14	15-24	25 & over
	-boxes-	-boxes-	-boxes-	-boxes
1969-70	1.8	3.8	6.1	7.6
1970-71	2.3	4.6	5.1	8.1
1971-72	2.4	5.4	7.1	9.3
1972-73	2.7	4.5	6.9	8.5
1973-74	3.8	4.1	6.2	8.6
1974-75	3.7	4.7	6.4	8.3
1975-76	2.7	5.5	6.2	8.7
1976-77	3.4	5.3	6.3	9.1
1977-78	2.0	5.0	5.3	9.8
1978-79	2.3	4.7	5.5	9.7
1979-80	3.1	4.9	5.2	10.1
1980-81	2.5	4.2	5.0	9.2
1981-82	2.7	4.0	5.2	7.9
1982-83	2.6	3.0	2.9	8.4
1983-84	1.9	3.5	4.9	6.5
1984-85	3.0	4.3	5.7	6.3
1985-86	1.9	5.4	6.2	7.7
1986-87	4.1	5.1	6.1	8.7
1987-88	4.1	7.0	6.6	9.0
1988-89	4.9	6.4	6.3	7.7

Source: Florida Citrus Mutual, Annual Statistical Report, various issues.

Table 8.9. Actual Per Tree Yields of Colored Grapefruit for Various Age Classes, 1969-70 to 1988-89

Season	Age Class			
	4-9	10-14	15-24	25 & over
	-boxes-	-boxes-	-boxes-	-boxes-
1969-70	1.1	2.2	6.4	6.5
1970-71	1.6	5.2	6.9	6.2
1971-72	1.8	2.4	7.3	8.3
1972-73	2.3	5.2	5.8	8.1
1973-74	2.7	5.5	7.1	6.9
1974-75	2.5	4.2	6.0	7.0
1975-76	3.2	4.6	7.9	6.6
1976-77	2.2	4.7	5.9	6.8
1977-78	1.8	4.9	6.9	7.9
1978-79	3.5	3.9	3.9	6.2
1979-80	3.1	5.8	5.0	7.7
1980-81	2.7	3.2	4.4	7.2
1981-82	3.2	4.0	4.9	5.7
1982-83	1.7	2.8	4.5	5.7
1983-84	1.6	3.7	4.9	5.2
1984-85	2.9	4.8	5.4	5.7
1985-86	5.8	4.8	6.5	7.2
1986-87	4.1	5.7	5.9	6.5
1987-88	4.2	4.9	6.0	8.1
1988-89	4.5	5.7	5.7	7.4

Source: Florida Citrus Mutual, Annual Statistical Report, various issues

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